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POSTWAR MALARIA CONTROL IN CONTINENTAL UNITED STATES*

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(Received for publication 13 November 1945)

Today malariologists are in a unique position in the field of public health. At no time has malaria received wide-spread recognition and publicity comparable to the past two years. The press, radio, and popular literature have devoted more attention to malaria than any other single disease. The military significance of malaria as the Number 1 disease of most theaters, the high initial casualty rate among overseas troops, and the effect of returning carriers on the malaria potential of this country have been contributory factors. The result in Continental United States is unprecedented public awareness of malaria and, in general, a better public understanding of the causes and prevention of the disease. Combined with this background of heightened public sentiment are newly devised operational techniques, war developed materials, and early availability of of a reservoir of trained manpower. One might optimistically expect a decade of real achievement. The potentialities go beyond mere control of the disease and reemphasize the probabilities of eradication.

This paper does not attempt to blueprint the next decade of anti-malaria progress, but rather is a review of tangible factors that will influence its development.

In Continental United States, civilian malaria in the aggregate is at an all-time low; there has been little perceptible change in the past five years. Available data show a marked decrease in malaria rates among continental military personnel since 1941, but in these figures is reflected the extensive control programs in military areas. The cyclic upswing predicted for the early forties by some malariologists has not occurred. In the past two decades, reported malaria mortality and morbidity have dropped 85% and 70% respectively.

In World War I malaria control efforts were against the anopheline species. In the present emergency continental anti-malarial measures have clearly demonstrated on a larger scale the economy and effectiveness of utilizing fully deve'oped "species sanitation," i. e., application of entomological science to focus control energies

*Presented at the meeting of the National Malaria Society, Cincinnati, Ohio, 13 November 1945.

on the specific anopheline vectors. This practice produced satisfactory vector control in areas contigious to more than 2000 war establishments with less than 50% of the facilities required for the old system of seasonal scheduling.

The logical post-war step in the evolution of anti-malaria practice might well be integration of sound medical epidemiology with species sanatation. To insure success, there is desperately needed a more sensitive but practical technique to measure malaria incidence in the population. Recession has outmoded the thick film. Additionally, with continued low malaria rates, emphasis should be more and more on the prevention of potential hazards by avoiding the development of anopheline breeding areas as a by-product of other worthwhile activities.

In vector control, the determined value and development of DDT (dichloro diphenyl trichloro-ethane) is doubtless the greatest single anti-malaria salvage of the war. DDT is a potent adulticide both in thermoaerosols as a space spray and in its residual properties as a surface spray. DDT offers the first economical and practicable approach to the problem of rural malaria. The use of DDT as a larvacide will reduce application costs at least 70% in comparison to former larvicides. Wide-spread application of DDT must be in balance with its deleterious effects on useful biological life.

Major development in hand and power equipment, together with improved water management will materially revise the operational approach in the control of malaria vectors. Intelligent use of these new tools will certainly reduce and may well alleviate major controversial issues among allied water interests. The demonstrated value of modern training and educational techniques in malaria control operations is worthy of major postwar consideration. Preventive measures of some diseases, including malaria, require self protection on the part of individuals which can never, and perhaps should never, be completely substituted for by work of health agencies. Stimulation of the individual self-effort through educational media cannot be over-emphasized. Additionally, enlightened public sentiment is essential to the success of any health program. Basic research has made notable strides in recent years, particularly in the field of chemotherapy. Studies to determine if indigenous malaria vectors can transmit imported exotic strains of plasmodia have been completed. The answer in five words is—"they can with high efficiency". The several conclusions herein drawn are subjects of technical papers on the agenda of this meeting.

An effective modernized postwar anti-malarial program will depend upon the organizational ability and vision of responsible

health authorities of local, State, federal and allied agencies. The malariologists must stimulate and guide this trend, in addition to providing leadership in the over-all integration of sound malaria preventive practices in various programs involving water usage. Among fundamental issues, the most pressing is for clear delineation of functional responsibility at the federal level and at, and below, the State level. Obviously there is joint responsibility.

In 1942 the Public Health Service established in Atlanta (Georgia) the offices of Malaria Control in War Areas charged initially with prosecution of malaria control in the extra-cantonments of military and war industrial areas. In interim years responsibilities of this office have been broadened to include limited *Aedes aegypti* control ($350,000 per annum), expanded training activities ($450,000 per annum), anti-malaria measures in endemic areas ($5,000,000 per annum), control of murine typhus fever ($1,000,000 per annum), and, quite recently, the tropical disease program. With the splendid cooperation of the State Health Departments, the centrally directed programs made maximum use of the war-related shortages of manpower, materials and equipment.

The malaria office in Atlanta is now in a period of transition. War establishment malaria control has fulfilled its original purpose and is being liquidated concurrently with major demolization. Coincidental with demobilization, anti-malarial measures in major endemic areas are being strengthened to meet the full impact of returning malaria carriers. Of concern also is the increasing significance of other tropical diseases, both indigenous and exotic. Of the indigenous, in addition to malaria, murine typhus of the East and sylvatic plague in the West (now infiltrating eastward) are of particular import. As to introduction of exotic tropical diseases, attention is focused both on returning war personnel and the anticipated accelerated world aerial commerce. The potential of aviation is such that it may well be the more significant of the two.

There is now under development in Atlanta a facility, or center, designed to broaden the efforts of the Public Health Service in the field of Tropical and related diseases. The plan is based on a clear delineation of Federal - State responsibilities and proposes the following four main functions:

1. *Training.* Vocational internship type of training of Public Health Service Personnel as now established, including production and distribution of audio-visual and other training aids. Establishment of a diagnostic reference and training laboratory and library (including diagnostic specimens and materials).
2. *Epidemiology.* Specialized epidemiological service to the States;

definition and elucidation of the epidemiology of diseases; laboratory and field studies of tropical and related disease problems and control.

3. *Technical Development.* Development of equipment, materials and operating techniques for improving field control measures; biological and engineering investigations with emphasis on insects as related to public health.
4. *Field Operations.* Cooperative tropical and related disease control demonstrations with state health departments; technical consultation services to States and other agencies; operational assistance in emergencies; and other operations as may be prescribed by Public Law.

These various related functions, requiring similar professional skills and techniques, can be most economically and effectively administered under one office. The supporting laboratory facilities necessary for productive conduct of epidemiological and other investigations, operations, and training utilize common and interchangeable personnel and equipment. The close inter-relation and interdependence of the constituent functions require the integration into a single coordinated facility.

In meeting problems in tropical diseases, practicing physicians and local health departments constitute the main line of defense. Upon them will fall the task of recognizing, diagnosing, and treating tropical infection and instituting local preventive and suppressive measures. To render more effective these local efforts, specialized diagnostic, training, investigative and operational facilities not otherwise available must be provided. The proposed center would furnish these aids in addition to conducting operational investigations for developing control equipment, materials and techniques.

Research will be confined to those investigations which are closely coupled with, and vital to, adequate field epidemiology and development of control measures. In all phases of this program close liaison with the National Institute of Health and other groups will be continued to assure maximum utilization of basic information.

With intelligent leadership and specialized assistance, local medical and public health groups effectively can protect their respective communities. It is our considered opinion that the challenge of the emerging potential can most successfully be met by providing this leadership and assistance through the medium proposed.

While as yet the postwar problem of malaria and related discases is not entirely defined, tangible factors indicate an urgency for consolidation of efforts, delineation of responsibilities, and positive action.

SPECIES ERADICATION BY MEANS OF DDT

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(Received for publication 13 November 1945)

Two years ago here in Cincinnati, J. W. Mountin, of the U. S. Public Health Service, read a paper, "A Program for the Eradication of Malaria from Continental United States," in which a startling but stimulating suggestion was given to mosquito and malaria control workers everywhere. As I listened to the theory of malaria eradication in the United States and to the arguments of L. L. Williams that day, I could not help but foresee the role which the new insecticide DDT could play in the accomplishment of his plan. At that time, you will remember, the use of DDT as a mosquito-control agent was not generally known to the public. Indeed, only a few months before, this new synthetic was first recommended as a body louse control for military use. Sufficient tests had been made with DDT by the entomologists at Orlando, Fla., however, to suggest the use of the chemical as the most potent agent against mosquitoes, both larvae and adults, of which we have knowledge.

Since early in 1943, when the first sample of DDT was tested as a mosquito-control agent by E. F. Knipling and associates, millions of pounds of DDT have been used for the control of mosquitoes throughout the world by the Army, the Navy, the Rockefeller Foundation, the Pan-American Sanitary Bureau, the Office of Inter-American Affairs, and others. From practically all parts of the globe have come enthusiastic reports of its efficiency as a killer of annoying and disease-carrying mosquitoes.

At least two methods of control with DDT sprays—application by means of aircraft and residual or surface treatments, if used cojointly, appear to offer possibilities of species eradication in limited and localized areas. Both these methods were suggested by small-scale experiments at the Orlando laboratory. Later large-scale field trials were conducted in Arkansas in cooperation with the Army, the Public Health Service, and the Arkansas State Board of Health; in Alabama in cooperation with the Tennessee Valley Authority; in Florida and Panama in cooperation with the Army and Navy; and in Mexico in cooperation with the Rockefeller Foundation.

By means of the first method E. F. Knipling, A. W. Lindquist, C. C. Deonier, and others, of the Bureau of Entomology and Plant Quarantine, Capt. W. N. Sullivan and Capt. W. C. McDuffie,

and others, of the Army; and Comdr. H. P. Hopkins and others, of the Navy showed that it was possible to secure high reduction of *Anopheles albimanus* Wied. and other mosquitoes under average jungle conditions. In two tests which I witnessed in Panama during January and February 1945, remarkable kills of adult and larval mosquitoes were obtained with 5-percent DDT sprays applied from a B-25 and a C-47 airplane at the rate of 6 quarts of the spray per acre.

In one test an estimated 10,000 adult mosquitoes of several species were caught one night in a horse trap as part of an effort to determine the mosquito population in the 160 acres of jungle to be treated. The next morning, about 30 minutes before treatment, these mosquitoes were released. Twelve hours later, at dusk, the horse trap was baited again in an effort to obtain information on the number of mosquitoes remaining in the area; only 1 mosquito was caught. The second night after treatment 3 mosquitoes were caught, and for each succeeding night the number gradually increased to over 200 in two weeks.

In the second test an area of about the same size but containing a typical *A. albimanus* breeding area and bordering jungle was treated with a 5-percent DDT spray. The night before treatment the horse trap in this area captured an estimated 15,000 mosquitoes, and average dips in *Naias* nearby produced perhaps a dozen larvae in a total of 200 samples. Twenty-four hours after treatment the horse trap caught 86 mosquitoes and not a single larva could be found in the *Naias*.

The point I wish to emphasize is that in each instance one treatment reduced the mosquito population more than 99 percent. We can only conjecture the possibility of total eradication by daily applications for several weeks had the areas been isolated or had they been islands.

In 1944 near Stuttgart, Ark., J. B. Gahan, A. W. Lindquist, and others obtained amazing reductions of *Anopheles quadrimaculatus* Say in and about rice fields by applying once during the season a 5-percent DDT spray to the interior surfaces of all buildings and other places where these mosquitoes might find shelter in two areas each 3 miles square. Adult-mosquito populations in the treated buildings were reduced over 98 percent and larval populations more than 50 percent.

This experiment was so promising that we decided to conduct a similar experiment where a different but efficient vector of malaria existed. The locality chosen was near Cuernavaca, State of Morelos, Mexico, where *Anopheles pseudopunctipennis* Theo. was prevalent.

One treatment of a 5-percent DDT spray during April and May reduced the adult population 99 percent and the larval population over 90 percent, as compared with counts in untreated villages and rice fields near untreated villages.

It therefore seems to me that the time has come when agencies interested in the control of mosquitoes and malaria in various parts of the world can appropriately outline plans for species eradication. Initial tests might be made on such islands as Puerto Rico, Trinidad, Sardinia, Crete, and Hawaii, and in such countries as El Salvador, Costa Rica, and Italy. Other workers have also contemplated the practicability of species eradication. While I was visiting Guatemala less than two months ago Lt. Col. H. W. Van Hovenberg pleaded for a demonstration to show the possibility of anopheline eradication in El Salvador. More recently F. L. Soper has hinted of a similar experiment in Sardinia.

Already a $200,000,000 public-improvement program has been planned for Puerto Rico. The eradication of anopheline mosquitoes and malaria seems a most appropriate part of such a program. Approximately $100,000 has been spent annually during the last several years for the control of malaria on this island. Will it be necessary to continue these expenditures indefinitely? May it not be well worth the attempt to spend several times this amount in one season in a vigorous all-out effort to eradicate the last anopheline? Large-scale demonstrations are now justified by past pioneering and the promising results just shown. The eradication of *Anopheles gambiae* Giles from Brazil by F. L. Soper, D. B. Wilson, R. C. Shannon, and others, at a time when DDT was unknown, adds weight to our premise that other anophelines elsewhere are not invulnerable and can be meted out the same fate.

Innumerable difficulties of species eradication in large areas certainly will be encountered. To surmount them the most expert guidance will be essential. Moreover, great care should be taken that those in charge fully understand the dangers that can be caused fish and other forms of wild life by such treatments. Although the two methods of applying DDT as described will furnish these experts with their most effective tools, a program of this complexity surely should include also all the best known practices of mosquito control.

The advent of DDT and its development as a mosquito control agent by entomologists now furnish the world with a particularly effective vehicle towards the goal of species eradication.

EXTENT OF MALARIA RESEARCH IN THIS COUNTRY AND ABROAD

The Committee on Medical Research are making a survey of malaria research being carried on in this country and abroad. As space in the Journal permits and information becomes available we shall include as many of these items as possible. — The Editor.

Harvard University, School of Medicine and Public Health
Boston, Mass.
(Dr. Quentin M. Geiman)

Investigations have been directed along both biochemical and parasitological lines. They have included studies an antimalarial drugs in vivo and in vitro, and research on various aspects of cultivation of plasmodia in vitro.

Media and cultural techniques for promoting growth and multiplication of malaria parasites in vitro have been developed, and considerable success along this line has been reported. Studies on the essential nutrients required by plasmodia, and on the metabolism of the parasites, have been carried out, using the methods of in vitro cultivation already developed, and correlating the observations with in vivo studies.

The effects of hyperimmune sera on parasite in vitro are also being investigated.

Plasmodium knowlesi in monkeys and *P. lophurae* in ducklings are being employed, as well as the human species of plasmodia. All studies are being conducted on blood-induced infections.

The Rockefeller Foundation
New York Avenue & 66th Street, New York
(Dr. Wilbur G. Downs)

Plasmodium gallinaceum is being maintained in chicks and *P. cynomolgi* in monkeys. Sporozoite infections are available by passage through insectary-reared *Aedes aegypti* and *Anopheles quadrimaculatus* respectively. *P. gallinaceum* is also maintained in chick embryos.

The exo-erythrocytic stages of *gallinaceum* is being studied in chicks and in chick embryos, and trials have been made with maintenance of these forms in tissue culture.

Other lines of investigation include isolation of single organisms, studies on methods of diluting sporozoites for inoculation, and work on the metabolism of *P. gallinaceum* by means of the Warburg apparatus.

Drug tests, directed at all phases of *P. gallinaceum* infections, are being carried out.

Lederle Laboratories, Pearl River, N. Y.
(Dr. Redginal Hewitt)

The program at these laboratories is concerned with searching for new antimalarial drugs, including organic chemicals, plant extracts, and antibiotics. Blood-induced infections with *Plasmodium lophurae* in ducklings and *P. cathemerium* in canaries are being employed for testing purposes.

MALARIA MORTALITY AND MORBIDITY IN THE UNITED STATES FOR THE YEAR 1944*

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(Received for publication 13 November 1945)

This report constitutes the yearly assessment of the status of malaria in the United States for 1944, based on replies received from a questionnaire sent to the bureau of vital statistics of the forty-eight states, New York City and the District of Columbia. Because of the increased actual or potential importance of the disease in the military as well as civilian population within the respective major political subdivisions of the United States, an attempt was made, as in the previous report, (Faust, Scott and McDaniel 1945) to obtain information broken down into these two categories. Likewise an inquiry was directed into the significance of malaria as a therapeutic agent in the treatment of central nervous system syphillis, its prevalence in drug addicts and malaria survey activities for 1944. In all other respects the report conforms to earlier ones in this series.

Grateful thanks are extended to the directors of public health and their associates in the various states, New York City and the District of Columbia for the attention they have given to the questionnaire and to many personal letters which supplemented the formal inquiry. Appreciation is also expressed for the valuable clerical assistance of Mrs. Ann Richards and Miss Fay Gill, Department of Tropical Medicine, Tulane University.

The Record of the Malaria Deaths for 1944

The total number of certified civilian malaria deaths for the United States in 1944 amounted to 584, as contrasted with 622 net for 1943. The respective rates per 100,000 population were 0.44 and 0.47. Five hundred forty of this total (92.6 per cent) occurred in the fourteen Southern States, which have contained the heavily endemic foci for many decades (i. e., Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia). Thus, approximately one-third of the entire population still experiences more than nine-tenths of the entire death loss from this disease.

An examination of Table 1, in which total malaria deaths for 1943 and 1944 are compared for major political subdivisions, indicates an appreciable reduction of deaths in Alabama (rate 2.12 vs.

* Report of Committee on Statistics, presented at the annual meeting of the National Malaria Society, Cincinnati, Ohio, 13 November 1945.

1.38), Florida (rate 2.16 vs. 1.74), Mississippi (rate 3.69 vs. 2.79), Missouri (rate 0.66 vs. 0.37), Oklahoma (rate 1.28 vs. 0.77), and Tennessee (rate 0.72 vs. 0.44); a *status quo* in Arkansas, Georgia, Kentucky, Louisiana and South Carolina, and an appreciable increase in North Carolina (rate 0.59 vs. 0.81) and Texas (rate 0.84 vs. 1.15). Compared with the figures for 1940, 1941 and 1942 the 1943 and 1944 rates for Alabama, Florida and Mississippi show a continued decline year by year over the five-year period. Arkansas has had no significant decline in three years. After a decade of rapid reduction in the rate Georgia, South Carolina and Louisiana have reached a temporary equilibrium. Kentucky has manifested no important rate reduction in five years. North Carolina and particularly Texas show indications of a moderate resurgence of malaria.

Referring again to the more highly malarious Southern States, one is impressed with the marked shrinkage of highly endemic foci. Alabama had no county rate as high as 10 for 1944. In Arkansas, the rate declined from 35 to 15 in Lincoln Co., but it increased appreciably in Chicot, Desha, Miller, Monroe, Perry, Phillips, St. Francis and White Counties. Nevertheless, these eight counties constitute only a small fraction of the hyperendemic territory which existed in the state a decade ago. In Florida, the highly malarious areas have been reduced to a relatively minor hazard. In Georgia, only Seminole Co., in the southwest corner of the State, with no county health officer, has developed a danger signal, as indicated by a rate increase from 12 in 1943 to 59 in 1944. In Kentucky no evidence of appreciable increase has appeared in any county. In Louisiana, only Richland Parish has had an important rate increase during the year. In Mississippi, Coahoma Co. had a definite increase in rate but adjacent Quitman Co. had an even more apparent decrease. In North Carolina, both Brunswick and Washington Counties had a decided reduction in the rate, while in South Carolina Berkeley and Williamsburg Counties had definite increases. In Texas, Bowie Co., in the northeast corner of the State and Hidalgo Co. on the lower Rio Grande had increases; otherwise the malaria death increment for the State as a whole was generally distributed throughout the eastern third. No breakdown of deaths from malaria by counties in 1944 has been made available for Missouri or Oklahoma. While Virginia lies in the area of previous hyperendemicity, for more than a decade it has experienced no serious morbidity from the disease. In the Southern State other than Virginia, for which deaths by counties are available, the total number of counties in which there were deaths in 1943 as compared with 1944 has been reduced from 271 to 257. This reduction in mortality territory by

Table 1.—Malaria Mortality and Morbidity in the United States for 1944 by Major Political Subdivisions

State or Other Major Political Subdivision	Deaths 1943	Deaths Certified				Cases Reported				
		Civilians				Civilians				
		Acquired in State	Elsewhere Acquired	Military	Prisoner of War	Acquired In State	Acquired Elsewhere	Military	Prisoner of War	Total
Alabama	60	39				2271		611		2882
Arizona	0	0				10		50		60
Arkansas	108	117				1427				1427
California	3	7	1			84	54	1455		1583
Colorado	1	0	1			2		32		34
Connecticut	0	0				*1		61		62
Delaware	0	0				0		15		15
Florida	41	33				15		507		522
Georgia	37	34				314		102		216
Idaho	1	0				1		1		2
Illinois	9	3		1		**88		251	130	429
Indiana	6	10				80				80
Iowa	1	2				4		237		241
Kansas	3	1				13		78		91
Kentucky	13	15				27				27
Louisiana	29	29				ca734		ca735		1469
Maine	1	0	1			0				0
Maryland	0	0				0		23		23
Massachusetts	0	3		4		7		565		572
Michigan	3	0				18	6	218		242
Minnesota	1	1		1		1		59		60
Mississippi	74	61				22,398		735		23,133
Missouri	25	14				41		182		223
Montana	0	0				0		28		28
Nebraska	0	0				0		6		6
Nevada	1	0				4				4
New Hampshire	0	0				0		2		2
New Jersey	2	0				14		812		826
New Mexico	1	3			1	3		2	6	14
New York State	3	0				4	8	208	10	230
New York City	3	3		1		35		288		323
North Carolina	21	29				130		24		154
North Dakota	1	0				0	1	7		8
Ohio	5	5				17	4	133		154
Oklahoma	30	18				1329		49		1408
Oregon	0	1				22		421	7	450
Pennsylvania	1	1		1		2		343		345
Rhode Island	1	0				0		264		264
South Carolina	62	63				9478		421		9899
South Dakota	0	0				0				0
Tennessee	24	15				185		7		192
Texas	54	74				7498		575		8073
Utah	0	0				1		156		157
Vermont	0	0				0				0
Virginia	1	1				37		676		713
Washington State	0	1				4		4		8
Washington, D. C.	0	0				†7		164		171
West Virginia	0	1				3				3
Wisconsin	1	0		1		0		133		133
Wyoming	0	0				8		5		13
Total	627°	584								

*Following transfusion **Includes 65 therapeutic malaria †Includes one heroin addict
° Includes 5 acquired outside Continenatl U. S.

counties has been particularly noted for Alabama, Arkansas, Florida, Georgia, South Carolina and Tennessee.

An examiner of the malarious Southern States in 1944 is struck with the diminished number and size of the foci where the disease still produces death, as contrasted with the situation ten years ago and even in 1939. In the previous decade a large number of deaths from malaria occurred yearly in practically every county on the Atlantic Seaboard from the Potomac River to the tip of Florida and inland through the Piedmont Plateau. Similarly, nearly all of Alabama, Mississippi, Southeastern Missouri, Southern Illinois, Indiana and Ohio, Southwestern Kentucky, Western Tennessee, practically all of Arkansas except the northwestern corner, the northern two-thirds of Louisiana, the eastern half of Oklahoma and the eastern half of Texas all contributed to the relatively heavy toll. The present picture shows only the following hyperendemic spots: (1) the central coastal counties of South Carolina; (2) Seminole County, Ga.; (3) counties in the upper Mississippi delta, including seven in Arkansas, one in Mississippi and one in Louisiana; (4) two adjacent counties on the Red River, one in Texas and one in Arkansas, and (5) the lower Rio Grande valley. From the standpoint of death rates this is a very impressive indication of the progress in the elimination of malaria from the heavy seedbeds of the disease in the United States.

Although most of the States do not segregate deaths due to malaria acquired within a state from that acquired outside the state, a few do make this distribution. This serparation has been indicated in Table 1. Similarly, five Northern States and New York City have distinguished deaths which were due to malaria that had been acquired overseas on military duty, and New Mexico has listed one death from malaria in an Italian Prisoner of War. None of the certified deaths in this table include those which might be due to malaria as a therapeutic procedure in the treatment of syphilis of the central nervous system.

Reported Cases of Malaria

Reference is again made to Table 1, which shows that an increasing number of malaria cases based on blood film examination is being reported to State Boards of Health or is being conducted under their immediately supervision. This is indicated particularly for certain Southern States in which malaria is still prevalent. Mississippi, South Carolina and Texas have notable reports in this entry. An inspection of the table indicates that California, Michigan, New Mexico, New York State, North Dakota, Ohio and Rhode Island have segregated individuals into those who were exposed to malaria

within the State and outside the state. Forty-two of the fifty political subdivisions have also entered positive blood film examinations made on military personnel within their territory. In some instances these were request examinations made on personnel in a military post, in other instances they refer to individuals in the armed services on furlough or on leave from military establishments. In some of the lightly malarious or non-malarious areas a considerable amount of valuable laboratory experience must have been acquired for the first time as a result of this diagnostic service. A few states (Illinois, New Mexico, New York, Oregon and Rhode Island) have included diagnoses of malaria on blood films from Prisoners of War.

The report on malaria cases is still unsatisfactory from most of the States in respect to the ratio of cases to deaths. This is a point which has been considered year by year with little evidence of improvement. During the epidemic of a decade ago it was suggested that in highly malarious areas there were probably about one hundred cases for each malarial death, and in more mildly endemic territory the ratio was possibly more nearly 200 to one. The only State which has reached this expectation is Mississippi, where for several years a 200 to one ratio has been demonstrated. Now, with malaria still extensively distributed but much more benign in character, the ratio in this State has been increased to approximately 300 to one. The nearest approach to this figure is that of South Carolina, with a 150 to one ratio, while that for Texas is 100 to one. There is cumulative evidence that, in every other state where malaria is prevalent, a very high percentage of cases either remains undiagnosed or is unreported to the State Board of Health.

As indicated previously, most state bureaus of vital statistics and epidemiology do not receive reports from State Hospitals or private physicians on the number of patients treated therapeutically with malaria parasites. This is amply confirmed in the 1944 survey of available data. Similarly, there is no large number of records of malaria in drug addicts.

Malaria Surveys During 1944

Included in the questionnaire was an inquiry into the activity of the Department of Health of each State, lesser political subdivisions or other interested agencies in conducting malaria surveys during 1944. Thirteen returns indicated that malaria surveys had been conducted during the year and 37 replied in the negative. In addition, six reports indicated that malaria-mosquito investigations had been made in 1944. A résumé of these activities follows.

In 7 northern Alabama counties (Colbert, Lauderdale, Lawrence, Limestone, Madison, Morgan and Jackson) blood-film sur-

veys were made by the Health and Safety Department of the Tennessee Valley Authority. A total of 5944 films were examined and thirteen found positive for malaria parasites (9 *Plasmodium vivax,* one *P. falciparum,* 3 undetermined). In Colorado the U. S. Public Health Service conducted a limited survey. In Florida 156 films were made from individuals living in Volusia and Sarasota counties, with no positives. In Georgia blood-film surveys were carried on in fifteen counties, totalling nearly six thousand individuals, two-thirds of whom were negroes. Of approximately three-fifths of this total examined microscopically as of October 31, 1945, only two were positive for malaria parasites. In Indiana studies were carried out in Marion County in the environs of Indianapolis. In Mississippi blood films were taken from 2,082 individuals in the vicinity of Sardis, Arkabutla, Enid and Grenada reservoirs in the northeastern part of the State. In North Carolina a malaria survey was conducted but no data were furnished to this Committee. In Oklahoma studies were made in cooperation with the U. S. Public Health Service and the U. S. Army Engineers; in Rhode Island in cooperation with the State Entomologist and a Malaria Control Unit of the U. S. Public Health Service, and in South Carolina under the direction of Dr. George E. McDaniel, Director of the Division of Preventable Disease Control. In Tennessee the Tennessee Valley Authority surveyed the Kentucky Reservoir area and found no positive films. In Utah the State University conducted a blood-film survey and in the District of Columbia the Malaria Control in War Areas of the U. S. Public Health Service was active.

Malaria mosquito surveys were reported from Connecticut (State Board), Kansas (U. S. Public Health Service), Michigan (Bureau of Engineering of State Department of Health and the U. S. Public Health Service), in Nebraska (State Entomologist), New York State (Where the U. S. Public Health Service carried out surveys for *Anopheles quadrimaculatus* in the vicinity of twenty military posts) and Virginia (where the Department of Sanitary Engineering investigated the mosquito problem in the Chicahominy Swamp Area following the impounding of water).

Special mention should be made of the mosquito survey conducted by the Connecticut State Board of Mosquito Control and the City of Norwalk within the limits of that municipality. Under professional direction volunteer workers covered the entire city, which had been divided into 198 collecting stations. In 42 of these stations (21 per cent) *Anopheles punctipennis* was found; in 15 stations (7.6 per cent), *A. quadrimaculatus;* and in one station (0.5 per cent), *A. barberi.*

Discussion

A careful examination of the available malaria data for 1944, as obtained from the bureaus of vital statistics of the departments of health of fifty major political subdivisions o fthe United States, indicates an over-all reduction in deaths due primarily to this disease. When these figures are compared with those previously secured and published by the National Malaria Society for the past decade, there is definite evidence that the decline since 1933-1936 has been sustained each year since that period of epidemicity. Not only has the total of deaths steadily decreased but the areas of hyperendemicity in the Southern United States have materially shrunken.

There is still evidence in the reports received that a proportion of the deaths are certified without blood-film confirmation and a suggestion that in some cases malaria is certified as the primary cause of death when actually it is only contributory. These are factors which make the data less valuable than they otherwise would be, yet they are not sufficient in quantity to invalidate the main conclusion, that malaria is year by year becoming a less important cause of death when considered from the viewpoint of vital statistics.

No special attempt has been made to determine the reasons for the continued favorable decline in the malaria death rate. It may be due to decreased opportunities of exposure to infected Anopheles mosquitoes, or it may result from a gradual reduction in the malignancy of the disease. Undoubtedly the breeding of malaria-transmitting mosquitoes has been greatly reduced within the previous decade, and particularly since 1942, when special agencies were set up within and around military posts throughout the entire country to reduce the malaria hazard for troops in training. This has obviously had its effect on the surrounding civilian population, since they, too, have had fewer chances of exposure.

The second possibility, namely reduction in the malignancy of of malaria in the United States, is more difficult to evaluate. Nevertheless, there are three indications that malaria is possibly less fatal than it was a decade or more ago. Increasing service of state boards of health laboratories in the blood-film diagnosis of the disease has made it possible to treat infection earlier with antimalarial drugs. In the second place, better nutrition of the poorer classes has undoubtedly contributed to their resistance to malaria as a serious, at times fatal, disease. In the third place, direct and indirect evidence that the number of cases per death in the more highly malarious Southern States is increasing, suggests that falciparum malaria may be proportionately decreasing compared with vivax malaria. Accurate

species diagnosis of the malaria parasites encountered in examining blood films has unfortunately been very difficult to obtain. However, the data included in the previous report of this Committee (Faust, Scott and McDaniel 1945) show that with the exception of Georgia and North Carolina vivax is considerably more common. If this information accurately represents the present situation, it provides a partial explanation for the decrease in deaths, since falciparum malaria is much the more common cause of death.

The number of cases of malaria reported by State bureaus, and hence received by them from State agencies directly concerned with malaria, is notable in its inadequacy. With few exceptions there is still incomplete information regarding the actual endemic distribution of the disease in the United States. The map which one member of this Committee published in 1945 (Faust 1945), based on 1943 data, shows that there are extensive regions of endemicity where deaths have been certified without records of cases. With the continued efforts of anti-malaria and anti-anopheline agencies in these areas in 1944 and 1945 it will probably be instructive to have a similar spot-map of endemic territory at the end of this period, to determine if the endemic area has increased or shrunken.

Attention has been focused during 1944 on the large number of cases of malaria which resulted from exposure overseas and were diagnosed by State laboratories. Undoubtedly these represent only a small proportion of vivax-infected individuals who had been in military service in highly malarious area outside the Continental United States and had returned to the United States. Atabrine discipline in the suppression of clinical malaria has proven to be highly effective. It has almost completely eliminated falciparum infection but in potential vivax exposures about five per cent of all troops under atabrine discipline have broken through from one to several months after suppressive atabrine treatment has been discontinued. Thus, there were possibly a total of 50,000 clinical cases of vivax malaria among returned troops in 1944, while a considerably larger number may be anticipated for 1945 and 1946. The majority of these have been diagnosed in military hospitals and some of the diagnoses made by State laboratories are undoubtedly confirmation of known infections. The danger lies in infections developing among discharged troops or those on furlough in areas where Anopheles mosquitoes are breeding in numbers and may pick up the infection and transmit it to the civilian population. This suggests increased precautions during the next few years to prevent the establishment of exotic strains of malaria in actual or potential areas of endemicity. In this respect Prisoner of War camps constitute a minor but similar hazard.

All in all, the picture of malaria in the United States continues to be more favorable yearly. It must be suggested, however, that this situation may change if with post-war retrenchment the potential dangers of the disease are forgotten by the fiscal agencies responsible for the financing of anti-malarial work.

Conclusions and Summary

1. The malaria mortality data for 1944, which have been obtained from the forty-eight States, New York City and the District of Columbia, indicate a continued reduction in deaths and rates. In 1944 there were 584 deaths, with a rate of 0.44 per 100,000 for the entire United States. Of this total 540 (92.6 per cent) occurred in the more malarious South. The favorable condition was due particularly to reduced deaths from malaria in Alabama, Florida, Mississippi, Missouri, Oklahoma and Tennessee, as contrasted with North Carolina and Texas, in which the rates increased from 1943.

2. The more highly endemic regions in the South have materially shrunken within the last quinquennium.

3. Malaria deaths outside of the South are becoming less frequent and of those certified the majority have resulted from exposure in the South or outside the United States.

4. There is evidence that certified deaths due to malaria are at times not confirmed by blood-film diagnosis, while in other instances malaria is probably only contributory to death.

5. Cases of malaria are reported from a considerable proportion of the States outside of the South. Many of the diagnosed individuals have been in military service overseas, a few were prisoners of war and only a small number bear evidence of having acquired the infection within previously known but mildly endemic areas in this country.

6. Civilian infections reported to State boards of health do not adequately reflect the malariousness of the respective area. Very few States have records approximating the actual number of cases of malaria existing within their area.

7. Very few state agencies carried out malaria or anti-mosquito campaigns in 1944.

8. The discharge to civilian life of military forces with recurring vivax malaria may constitute a serious public health hazard in areas where Anopheles mosquitoes are allowed to breed in numbers, unless anti-mosquito campaigns continue to be vigorously prosecuted.

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RECENT DEVELOPMENTS IN THE USE OF DDT AND OTHER MOSQUITO INSECTICIDES AND REPELLENTS[1] [2]

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(Received for Publication 14 November, 1945)

In a previous report presented before this Society (Knipling 1945), the results of two years of investigations with DDT for the control of mosquitoes were discussed. This work had been done by members of the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, where investigations on the control of insects and arachnids of importance to the armed forces have been under way since 1942. This report gives a brief resumé of studies conducted on DDT and certain other insecticides and repellents since the last meeting.

Residual Treatments For Adult Mosquitoes

DDT as a Residual Treatment. — Since May 1945 experiments have been under way in certain villages in Mexico to study the effects of DDT residual (or surface) applications for the control of malaria and to make observations on the effects of such treatments on both adult and larval populations of *Anopheles pseudopunctipennis* Theob. This project has been carried on jointly by J. B. Gahan of the Bureau of Entomology and Plant Quarantine and G. C. Payne of the Rockefeller Foundation.

Time has not permitted an evaluation of the treatments with respect to their effect on malarial incidence among inhabitants in the villages treated with DDT. However, a number of important observations have been made on the effects of the treatment on the mosquito population in one of the villages. Two villages, Temixco and Acatlipa in the State of Morelos, were chosen for the experiments. These villages are in a valley where rice culture is the major agricultural pursuit. All the houses and other structures within the village of Temixco (population approximately 1,400) were treated with a 5 per cent DDT emulsion prepared from a concentrate containing 25 per cent of DDT, 7 per cent of Triton X-100 (an aralkyl polyether alcohol), and 68 per cent of xylene. The emulsion was applied at the rate of 200 mg. of DDT per square foot. The village

[1] This paper was presented at the annual meeting of the National Malaria Society in Cincinnati, Ohio, 14 Nov., 1945.

[2] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine .

of Acatlipa, having a population of 800 and located only 1 mile from the limits of Temixco, was used as a check. The spray was applied during April and May. Observations on the populations of adult mosquitoes in both villages were made throughout the remainder of the season. Regular dipping records were also made to determine the effects of the residual treatments on the larval populations in the adjoining rice fields of each village. Results of similar studies conducted in 1944 against *Anopheles quadrimaculatus* Say in the vicinity of Stuttgart, Ark., have been reported by Gahan and Lindquist (1945).

Counts of adult mosquitoes made at intervals of 2 weeks in a representative number of treated buildings in Temixco averaged from 0.05 to 0.15 for almost 5 months. Similar counts made in the control village averaged 56 to 160 adults per building for the same length of time. In pretreatment counts the adult population was 15 per building. These results indicate that one treatment under conditions in the villages will give a high degree of control of adult *Anopheles pseudopunctipennis* for at least 5 months, which is in line with results obtained against *A. quadrimaculatus* in Arkansas.

Pretreatment counts indicated that the larval population in the rice field around Temixco was somewhat higher than that in the check area. The first two observations, made during the latter part of May after completion of the treatment, showed an average of 0.42 larvae per dip as compared with 3.7 larvae per dip in the check area. Thus, a drop in larval population of about 90 per cent resulted from the treatment. During the next month similar results were obtained From the third to the fifth month the larval population in the treated area ranged from 76 to 83 per cent lower than in the untreated area.

It is believed that at least some of the larvae in the rice fields near the treated village result from adults infiltrating from the check area nearby. Next season it is planned to treat both villages. This area will then comprise an isolated unit, since there is little or no mosquito breeding within several miles of these villages. It is also possible that the adults and larvae from these areas may be almost completely eliminated with the residual treatment alone.

Pyrethrum as a Residual Treatment.—According to Gahan *et al.* (1945) pyrethrum applied as a residual treatment is highly effective against adult mosquitoes. A recent report by Metcalf *et al.* (1945) also shows remarkable insecticidial properties for pyrethrum applied as a residual treatment.

Other studies have been conducted with pyrethrum in combination with certain pyrethrum synergists or activators. "Piperonyl cyclohexenone" combined with pyrethrum proved a far more effec-

tive and much longer lasting treatment than pyrethrum alone. A single treatment under laboratory conditions, applied at the rate of 100 mg. of pyrethrins and 400 mg. of "piperonyl cyclohexenone" per square foot, remained effective against adult *Anopheles quadrimaculatus* for at least 22 weeks, and against the housefly (*Musca domestica* (L)) for 10 weeks. Pyrethrum alone at twice the dosage was effective against flies for only 8 days.

Residual treatments containing as little as 5 mg. of pyrethrins per square foot in combination with activators remained effective against mosquitoes for at least 7 weeks, whereas pyrethrum alone at the same dosage remained effective 1 week.

A number of synthetic organic compounds other that DDT have been tested for their residual property. Benzene hexachloride is very promising, but the commercial product has a strong and persistent odor which is objectionable.

Airplane Application of DDT for the Control of Larvae and Adult Mosquitoes

Particle Size, Concentration of DDT, and Time of Application.—Results of studies conducted at the Orlando laboratory in 1942-1944 on the application of DDT from airplanes for control of mosquitoes have been reported by Lindquist *et al* (1946) and Lindquist and McDuffie (1946), Deonier *et al.* (1945), and Wisecup *et al.* (1946). Much of the research on this problem during 1945 was devoted to determining the optimum particle size of the spray for both adults and larvae, and to the relation between the amount of DDT applied and the total amount of spray.

Studies on the relative effectiveness of early-morning versus midday applications were also conducted by J. S. Yuill, A. H. Madden, A. W. Lindquist, and J. R. Mackey. These tests were made against salt-marsh mosquitoes (*Aedes sollicitans* Walk, and *A. taeniorhynchus* (Wied.)) in junglelike areas along the coast of Florida. Most of the tests were conducted in cooperation with the U. S. Coast Guard and the Bureau of Medicine and Surgery of the U. S. Navy, using a Coast Guard Sikorsky helicopter HNS-1. Additional tests against salt-marsh mosquitoes were conducted in cooperation with the DDT Committee, Army Air Forces Board, Air Forces Center, Orlando, Fla., using a C-47 airplane equipped with a thermal generator[3] and a B-25 plane equipped with a straight discharge pipe.[4]

[3] Designed by the National Defense Research Committee.

[4] Designed by personnel at Wright Field, Dayton, Ohio, and the National Defense Research Committee, Urbana, Ill., and tested extensively in 1944 with the DDT Committee, the Army Air Forces Board, Air Forces Center, Orlando, Fla.

Results of several replicate tests, principally with the helicopter, indicated that no significant difference in the control of adult salt-marsh mosquitoes was obtained by applying the same quantity of DDT in the form of a 5 per cent or a 20 per cent solution. This was true with a spray in which 90 per cent of the particles were below 100 microns in diameter, as well as with one in which only 40 per cent were below 100 microns and the remainder up to 460 microns; also no differences in effectiveness against adults were apparent with these sprays. The time of application of the spray likewise did not seem to be an important factor.

It should be pointed out that data obtained against salt-marsh mosquitoes in connection with the application of treatments for adults are difficult to evaluate. The rates of infiltration of mosquitoes from surrounding areas vary from time to time and results are generally erratic. The studies indicate, however, that particle size and concentration of DDT are not factors that have to be considered in the practical application of aerial sprays.

Area Control of Anopheles Mosquitoes.—An experiment with aerial sprays for the control of both adults and larvae of *Anopheles quadrimaculatus* and *A. crucians* (Wied.) was conducted near Dereduction after 6 hours. In the area treated with the B-25 no reland, Fla., in cooperation with the Army Air Forces Center. Three tests were made in two adjoining areas of approximately 1 square mile each. The populations of both larvae and adults were high. One area was treated with a B-25 plane equipped with the gravity-feed discharge pipe, which produced particles averaging about 200 microns. The other area was treated with a C-47 airplane equipped with the thermal generator, which produced particles averaging about 75 microns. A 20 per cent solution of DDT in S/V Culicide Oil B[5] was employed in each test for both types of equipment. A dosage of 0.3 pound of DDT per acre (1½ pints of solution) was applied in the first and third tests and of 0.6 pound (3 pints of solution) in the second test.

In the first test a heavy rain fell several hours after the sprays were applied. No doubt this interfered with a proper evaluation of the data, and although fairly good results were obtained they will not be discussed here. In the second and third tests nearly 100 per cent control of both larvae and adults was obtained in each area.

The fine spray particles produced by the C-47 caused a marked reduction of adult *Anopheles* within 2 hours and an even greater

[5] Mixture of polymethylnapthalenes and similar to Velsicol NR-70 (chiefly tetramethylnapthalene), which was first employed by the Tennessee Valley Authority in applying highly concentrated DDT sprays from airplanes.

duction in the number of mosquitoes was evident after either 2 or 6 hours.

Several important deductions can be made from these tests. Excellent control of the adults of *Anopheles* inhabiting buildings and of the larvae can be obtained with DDT at the dosages employed. No difference in final results is indicated for the fine and coarse sprays. However, evidence is accumulating which strongly indicates that the finer particles give a high degree of kill by contacting the insect, the residual effect (insects contacting spray particles on surfaces) being less important. When coarser particles are employed against *Anopheles* resting in sheltered areas, mortality is due almost entirely to insects contacting the contaminated surfaces. This information may be of great importance as a guide in further development of methods, time of application, and types of formulations.

It is significant that excellent and almost equal results were obtained with both types of equipment, and with both 0.3 or 0.6 pound of DDT per acre. However, these dosages were too high to answer the important question as to the most effective particle size for the spray.

Area Control of Salt-Marsh Mosquito Larvae.—The problem of getting larvicidal sprays to penetrate the dense vegetation found on many salt marshes in sufficient quantity to give satisfactory control of *Aedes taeniorhynchus* and *A. sollicitans* has been *investigated* during the past season. When applications were made with a Stearman plane equipped with a breaker-bar unit, recently designed and constructed by C. N. Husman, O. M. Longcoy, and H. S. Hensley it was found that 2 quarts of 5-per cent DDT spray did not provide satisfactory control of these species in the denser areas. However, when 2 quarts of a 10-per cent DDT spray (0.4 pound of DDT per acre) was used, over 95 per cent control was obtained in eight tests and approximately 80 per cent in two tests made by C. B. Wisecup, W. C. White, and V. S. Minnich.

Other Studies On the Control of Mosquitoes

Larvicides.—During the past year thousands of new materials have been evaluated as larvicides for *Anopheles quadrimaculatus*. Some of these materials are worthy of mention. Certain analogs of DDT were among the most toxic materials tested. TDE (1, 1-dichloro-2, 2-bis (*p*-chlorophenyl) ethane) has been found to be equal to or perhaps slightly more toxic than DDT to *Anopheles* larvae (Deonier and Jones 1946). Of 73 DDT analogs tested by Incho none were equal to DDT although several were highly toxic. C. C. Deonier, H. A. Jones, H. L. Haller, Edna Hinchey, and H. H.

Benzene hexachloride, which has shown some promise as a larvicide, was found by British workers to be very effective against a number of insects. Benzene hexachloride is less effective than DDT against *Anopheles* larvae. It shows most promise when used in an oil solution, and in this form it is equal to DDT against *Culex quinquefasciatus* Say and *Aedes aegypti* (L.). In field tests against salt-marsh mosquitoes it proved somewhat less effective than DDT in fuel oil.

Toxicants and Activators for Use in Space Sprays and Aerosols.—Approximately a thousand materials have been evaluated as toxicants or pyrethrum activators for possible use in space sprays. As toxicants none of these proved equal to DDT, Thanite, (isobornyl thiocyanoacetate), Lethane 384 (an aliphatic thiocyanate), or pyrethrum. As activators, however, a number of materials have been found that offer promise. "Piperonyl cyclohexenone" increased the knock-down and kill of adult *Anopheles quadrimaculatus* to some extent, but was more active against the housefly. Sesame oil concentrate showed good results against both mosquitoes and houseflies. Sesame oil was first shown to possess synergistic properties by Eagleson (1940) and has been widely used in liquefied-gas aerosols (Haller *et al.* 1942). The concentrated form, however, is much more active as a synergist than the ordinary oil. Two other compounds containing the methylenedioxyphenyl group, 4 (3, 4-methylenedioxyphenyl)5-methyl-1, 3-dioxane and 2(3, 4-methylenedioxyphenyl)4, 4-diethyl-1, 3-dioxane, were shown to be good, pyrethrum activators when employed against adult mosquitoes and houseflies. A number of other compounds containing the methylenedioxyphenyl group also show promise.

New Formulations of DDT.—A number of emulsifiers[6] and solvents (Jones *et al.* 1945) have been found that may be substituted for the triton X-100 and the xylene in the DDT emulsion concentrate used for residual sprays and as a larvicide. The emulsifiers Triton X-155 (polyalkyl aryl polyether alcohol), Tween 80 (sorbitan monooleate, polyoxyalkylene derivative), Igeal CA Extra High Concentration (alkyl aryl polyglycol ether) and an equal mixture of Span 20 (sorbitan monolaurate) and Tween 20 (sorbitan monolaurate polyoxyalkylene derivative) are especially promising, and solvents such as PD-544-C (lower fraction of S/V Culicide Oil B), and Velsicol AR-40 (chiefly monomethylnapthalene) or AR-50 chiefly mono- and dimethylnapthalenes) are satisfactory substitutes for xylene and in some respects superior to this solvent.

[6] Jones, H. A., Titus, H. A., and Oberg, M. W. Manuscript submitted for publication.

Mosquito Repellents. — The mosquito-repellent program has been intensified during the past year. Various university groups under the sponsorship of the Office of Scientific Research and Development[7] have prepared several thousand compounds, most of them related to previously known repellent materials, and these have been evaluated against *Aedes aegypti* and *Anopheles quadrimaculatus*. In addition, over a thousand compounds were obtained through commercial sources. No repellents were developed for use on the skin to prevent bites by mosquitoes. However, about a dozen materials that have been shown to be safe from a toxicological standpoint[8] were added to the list of repellents found to be equally as effective against *Aedes aegypti* as are other repellents previously reported. This work was done by B. V. Travis, F. A. Morton, and J. H. Cochran. One of the most promising of these against *A. aegypti* is 2-phenylcyclohexanol[9]. As has been found previously, very few of the materials show good repellent action against *Anopheles quadrimaculatus*. The best repellent for *A. quadrimaculatus* which is also effective against *Aedes aegypti* is beta-tetralol, prepared by chemists at Harvard University. Biological data obtained in connection with the repellents for use as skin applications are being summarized by F. A. Morton, J. H. Robinson, and B. V. Travis.

Several thousand repellent materials have also been evaluated to determine their effectiveness when applied to cloth. According to Travis and Morton the use of repellents on clothing as an adjunct to the skin treatment has shown considerable promise. A number of materials, principally solid chemicals tested by J. P. Linduska and F. A. Morton of the Orlando staff, have indicated good repellent action when impregnated in cloth.

Summary

Studies conducted at the Orlando, Fla., research laboratory during 1945 on the control of mosquitoes are briefly discussed. DDT residual treatments employed against adults of *Anopheles psuedopunctipennis* Theob. in Mexico are indicated to be effective for at least 5 months. These results are similar to those previously obtained against *Anopheles quadrimaculatus* Say in the United States. In addition to reducing the number of adult mosquitoes in treated buildings, the residual treatment reduced by about 90 per

[7] Chemists from the following universities have contributed to this program: Harvard, Maryland, Ohio, Minnesota, Stanford, Columbia, Indiana, Illinois, and Wisconsin.

[8] All toxicological tests on effective repellent materials were conducted by the U. S. Food and Drug Administration.

[9] This chemical found too toxic for use since the preparation of this paper.

cent the larval population in rice fields surrounding a treated village.

The effectiveness of pyrethrum as a residual spray for adult *Anopheles quadrimaculatus* is increased and prolonged by the use of certain activators.

Excellent control of both adults and larvae of *Anopheles quadrimaculatus* and *A. crucians* (Wied.) was obtained with 0.3 and 0.6 pound of DDT per acre applied as an aerial spray. No difference in final results was apparent with a 20 per cent DDT solution applied by means of a gravity-feed discharge pipe on a B-25 airplane and a similar solution applied by means of a thermal generator on a C-47 plane. The C-47 equipment, which produced a finer spray, was more rapid in its action than the coarser spray applied with the B-25. It is believed that coarse sprays cause mortality primarily as a result of adult mosquitoes' contacting the sprayed surfaces, and the finer sprays by direct contact of the insect.

Satisfactory control of the larvae of *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* Walk. on salt marshes was obtained by airplane applications of DDT in 10 per cent solutions, or emulsion, at a dosage of 0.4 pound of DDT per acre.

TDE (1, 1-dichloro-2, 2-bis(*p*-chlorophenyl) ethane), a close relative of DDT, is equally as effective against anopheline larvae. Benzene hexachloride is less effective than DDT against anophelines, but in oil solution it is comparable to DDT against *Culex quinaquefasciatus* Say and *Aedes aegypti* (L.).

Two compounds containing the methylenedioxyphenyl group, 4(3, 4-methylenedioxyphenyl) 5-methyl-1, 3-dioxane and 2(3, 4-methylenedioxyphenyl) 4, 4-diethyl-1, 3-dioxane, indicated promise as synergists for pyrethrum when employed against adult mosquitoes and houseflies.

Several DDT emplsion concentrates utilizing different emplsifiers or solvents have been formulated which offer promise as residual sprays or larvicides.

Two repellent materials, 2-phenylcyclohexanol and beta-tetralol, are promising mosquito repellents.

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Tulane University School of Medicine, New Orleans

(Dr. Albert Miller & Dr. A. J. Walker)

At present *Plasmodium vivax* and *P. malariae* are being maintained. Sporozoites are available in insectary-reared *Anopheles quadrimaculatus* and in wild-caught *A. quadrimaculatus* and *A. crucians*. Studies on *P. lophurae*, formerly carried on in chicks, have been discontinued.

In addition to studies of an entomological nature, investigations are also being carried out on the fate of plasmodia in mosquitoes which do not serve as vectors, and on detailed morphological variations in South Pacific strains of *P. vivax*.

Studies on the effects of drugs, and on the nature of the paroxysm are being carried out incidentally to the malaria therapy of neurosyphilitics.

Parke Davis & Company, Detroit

(Dr. A. C. Bratton)

The Research Laboratories of this Company are synthesizing new compounds as possible antimalarials. Tests of the drugs against blood-induced infections of *Plasmodium gallinaceum* in chicks and *P. cathemerium* in canaries are being carried on elsewhere, but it is expected that the entire program will soon be brought into the Company's research laboratory.

Malaria Institute of India, Delhi

(Major-General Gordon Covell, Lieutenant-Colonel M. K. Afridi)

The effects of antimalarial drugs are being studied in monkeys, as well as problems of immunity and relapse. The species of simian parasites in use are *Plasmodium knowlesi, cynomolgi,* and *inui*. Sporozoites of *P. cynomolgi* are available through *Anopheles stephensi, annularis* and *subpictus*.

Avian malarias are also employed in these studies, the species in use at present being *P. gallinaceum* and *P. relictum*. Sporozoites are obtained by passage of the former parasite through *Aedes aegypti, albopictus, vittatus,* and several others, and of the latter parasite through *Culex fatigans, raptor, mimeticus,* and *bitaeniorhyncus*.

Marquette University School of Medicine, Milwaukee

(Dr. Harry Beckman)

Studies are being conducted on survival of plasmodia (both trophozoites and sporozoites) in the blood fractions of non-susceptible species, the susceptibility of erythrocytes to invasion by plasmodia, and the effects of drugs, particularly from the standpoint of synergistic action. Drug studies also include the comparative susceptibilities to drugs of a given species in different hosts, and are directed at all phases of the parasite in the warm-blooded host.

Plasmodium cathemerium 3H2 is maintained in canaries, sporozoite infections being maintained by mosquito bites, employing insectary-reared *Culex pipiens*. Blood-induced infections are also utilized for certain of the studies.

Rutgers University, New Brunswick, N. J.

(Dr. Leslie A. Stauber)

Attempts are being made to develop a serological diagnostic test that would be sensitive enough to distinguish between the different species of plasmodia. Blood induced infections with *Plasmodium lophurae* and *P. cathemerium* in ducklings are used, but plans for extensions to other species are being made. The studies have been carried on in cooperation with the Squibb Institute.

EFFECT OF DEFICIENCIES IN VITAMINS AND IN PROTEIN ON AVIAN MALARIA*

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(Received for publication 13 November 1945)

The association between pestilence and famine has been recognized since biblical days. Those parts of the world where malaria is endemic are also the areas where malnutrition is particularly widespread. Only recently has it been possible because of the great progress in the field of nutrition to study the relation between nutrition and infection in the experimental animal. Several reports have recently appeared which deal with the effect of certain nutritional deficiencies on avian malaria.

The first report on the effect of a specific vitamin deficiency on avian malaria was that published by Trager in 1943 (Traeger 1943). He found, and his observations were confirmed (Seeler et al 1944), that the infection as judged by the parasitemia was more severe in the biotin deficient bird than in the bird receiving a diet adequate in biotin. Later, when we were able to produce the deficiency syndrome in chicks by means of a highly purified diet lacking biotin[1], we observed with *Plasmodium lophurae* infections a peak parasite count of 29.2 per cent in 14 deficient chicks and the significantly lower value of 19.5 per cent in 14 chicks given the purified diet with an adequate supply of biotin (Fig. 1). Thus an increased parasitemia was associated with biotin deficiency regardless of whether the deficiency was caused by making the biotin present in a stock diet unavailable through the use of dried raw egg white (Trager 1943) and (Seeler et al 1944) or by complete omission of biotin from a highly purified diet.

Parasite counts in *P. lophurae* infections in birds deficient in folic acid were also much higher than in birds on an adequate diet (Seeler and Ott 1945). Continued passage through folic acid deficient chicks neither increased the severity of the infection beyond that observed in the initial passage nor altered the basic virulence of *P. lophurae*. Later in two experiments with highly purified diets

* Presented at the meeting of the National Malaria Society, Cincinnati, Ohio 13 November, 1945.

[1] Diet B (biotin deficient): cerelose 56, vitamin-free casein 25, calcium gluconate 5, wheat germ oil 4.5, salts 3.5, glycine 2.5, Wilson's liver fraction L 2, arginine 0.5, 400D fish liver oil 0.5, cystine 0.2, choline 0.2, inositol 0.1, p-amino-benzoic acid 0.03, niacin 0.01, calcium pantothenate 0.004, riboflavin 0.002, pyridoxine 0.002, thiamine 0.002, and menadione 0.0004 grams.

deficient or adequate in folic acid[2], we found peak parasite counts of 42.4 per cent in 32 deficient chicks and of 28.4 per cent in 30 chicks receiving adequate folic acid, thereby verifying the previously reported relation between folic acid deficiency and the malaria parasitemia.

It became apparent, however, when riboflavin deficiency was studied (Seeler and Ott 1944) that a specific vitamin deficiency did not always result in increased parasite counts. The parasitemia in riboflavin deficient chicks was very significantly lower than in chicks given an excess of riboblavin in the diet. Futhermore, the administration of riboflavin to infected deficient chicks promptly increased the parasitemia. However, in spite of the low parasite counts, mortality among the infected deficient birds was very high, whereas the disease was benign in the chicks receiving an adequate supply of riboflavin.

[2] Diet deficient in folic acid: Diet B minus fraction L, plus 2 gms. cerelose and 0.04 mg biotin. Diet adequate in folic acid: Diet B plus 0.04 mg. biotin.

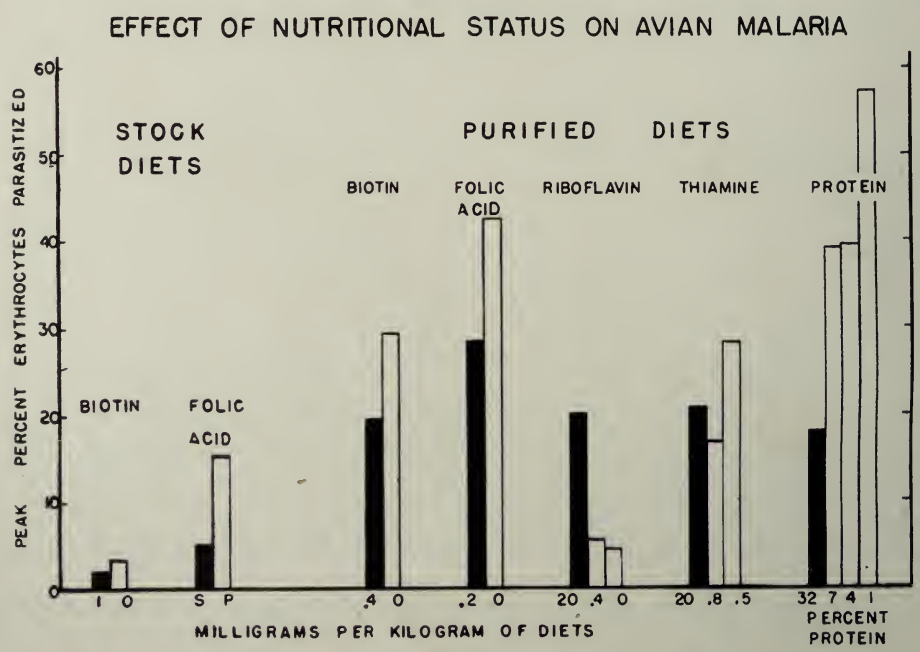

Fig. 1.—The effect of diets adequate (■) or deficient (□) in each of 4 B vitamins and in protein on *P. lophurae* parasitemia in chicks. S: commercial starting ration; P: highly puried diet containing no source of folic acid. The folic acid (0.2 mg.) in the adequate purified diet wa sestimated from its content of fraction L.

To extend the investigations in vitamin deficiencies, the effect of thiamine deficiency on the course of *P. lophurae* infections was studied in a series of experiments with graded levels of thiamine in the diet. In order to promote survival of chicks through the period of the acute infections, it was necessary to add 0.3 milligrams or more of thiamine per kilogram of the highly purified diet[3] used in these studies.

Table 1—Effect of thiamine deficiency upon *P. lophurae* infection in chicks.

Exp.	Thiamine added per. kgm. diet.	Per cent parasitized erythrocytes on		Survivors on 9th day
	mgm.	7th day	9th day	alive/total
1	0.8	7.7	3.4	16/20÷
	20.8	14.6	5.4	15/15
2	0.8	20.3	29.5	20/20
	20.0	20.0	31.6	15/15
3	0.5	28.4	18.0	3/15÷
	0.7	11.9	12.5	15/15÷
	20.0	21.8	19.5	14/14
4	0.4	28.0	27.5	6/20÷
	0.5	17.7	23.2	9/20÷
	0.6	16.9	19.5	8/20÷
	0.7	21.3	17.8	11/20÷
	0.8	19.7	19.7	13/20÷
	1.0	17.1	15.7	18/20÷
	1.2	19.4	20.7	20/20
	20.0	17.9	19.4	20/20

÷ High incidence of polyneuritis, characteristic sign of thiamine deficiency.

The relation of thiamine deficiency to the course of the malaria infections in chicks appears to be biphasic (Table 1). The parasite counts were highest in severely deficient chicks and lowest in chicks receiving dietary levels of thiamine approaching the minimum requirement of the chick. On the other hand, parasite counts in chicks given a large excess of thiamine tended to fall between those of the minimal and of the severely deficient groups.

In the studies on the effect of protein deficiency (Seeler and Ott 1946), it was observed that, as in the case of biotin and folic acid deficiencies, the parasitemia was very significantly higher in protein deficient chicks than in chicks given an adequate dietary supply of protein. Protein deficiency which was not severe enough to decrease the total serum protein had a pronounced effect in increasing the parasitemia. In addition it was found that chicks subsisting on diets deficient in protein were unable to clear the parasites

[3] Thiamine-deficient diet: Diet B. minus fraction L, thiamine and 8 gms. cerelose; plus 10 gms. autoclaved yeast and 0.04 mg. biotin.

from their blood streams as completely as chicks receiving ample protein. Moderate parasitemia still persisted in the protein deficient chicks as late as 4 weeks after inoculation, whereas the infection disappeared at a much earlier date in the well-nourished birds.

The fact that the *P lophurae* infections in chicks fed adequate purified diets showed almost constant peak parasitemias in these experiments indicates that the severity of the infection has remained lagely unchanged. While the peak parasitemias in chicks given adequate purified diets were considerably higher than the peak parasite counts in chicks on stock diets consisting of natural foodstuffs, the disease was benign with both types of diets. In fact, the growth of the chicks receiving adequate purified diets was frequently superior to that of the chicks on the stock diet. A satisfactory explanation is not yet apparent for the difference in parasitemia in chicks on the two types of adequate diets.

Summary

Parasite counts in *P. lophurae* infections in well-nourished chicks were less than in infected chicks deficient in biotin, folic acid or protein. On the other hand the parasitemia was less in chicks deficient in riboflavin than in the well nourished chicks. In the case of thiamine, the parasitemia appeared to be lower in chicks receiving approximately the minimal dietary requirements for normal growth than in either severely deficient chicks or in chicks given excess thiamine. Parasitemia in chicks fed a diet of natural foodstuffs was lower than in chicks given purified diets complete in all recognized nutrients.

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OBSERVATIONS ON THE BIONOMICS OF THE PRINCIPAL MALARIA VECTOR IN THE NEW HEBRIDES-SOLOMON ISLANDS[1]

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(Received for publication 14 September 1945)

Distribution and Taxonomy

Anopheles punctulatus and its close relatives form a dominant part of the anopheline population from the Moluccas through New Guinea, the Bismark Archipelago, the Solomon Islands, and the New Hebrides. It is not unlikely, therefore, to suppose that over such a wide area considerable variations in morphological and biological characters would naturally exist within the species. Extensive collections made over a period of two years indicate that at least two, probably three, and possibly more subspecies exist, each with a restricted geographical distribution and each with certain morphological characteristics distinct in egg, larval, and pupal stages.

First to describe a member of this complex group was Donitz, who in 1901 named the mosquito from the north coast of New Guinea *Anopheles punctulatus* and characterized it as "having the apical half of the female proboscis pale."

Later, Swellengrebel and Swellengrebel de Graaf (1920) reported from the Moluccas and Dutch New Guinea the discovery of an adult female with an entirely dark proboscis and the larva with thickened submedian prothoracic hairs, the tubercles of which were often fused. This mosquito was named *Anopheles annulipes* var. *moluccensis,* but only a year later Edwards (1921) recognized the relationships of this variety, forming a new combination, *Anophele punctulatus* var. *moluccensis,* and this term has since been generally adopted. In the meantime, Laveran (1902) named as *farauti* an anopheline from the New Hebrides with an entirely dark proboscis (exclusive of the labella). The synonymy of *Anopheles farauti,* however, is not clear and must await a re-examination of the type series if it still exists. Knight and Farner (1944) have published a correction in nomenclature indicating that Laveran's name should be used for the anopheline found on the New Hebrides. Since Laveran indicated that he observed a long series of specimens,

1. This article has been released for publication by the Public Relations Bureau of the United States Navy. The opinions and views set forth in this article are those of the author and not to be construed as reflecting the policies of the Navy Department.
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this would give credence to the view that he was describing the common anopheline of the New Hebrides which is also generally distributed throughout the whole of the Solomons.

In the opinion of the author, it is unlikely that Laveran would have described a series of specimens from the New Hebrides which were actually *Anopheles punctulatus punctulatus*, for the dark beaked form described by Laveran as *farauti* was the only species collected during two years' observations in the New Hebrides.

If, however, the New Hebridean form does differ appreciably from that of New Guinea, the name *farauti* may be used subspecifically for the form from this area. Until comparisons can be made with the type *moluccensis* and with reared material from the New Guinea the exact relationship of *moluccensis* to *farauti* cannot be determined, although the larvae of *moluccensis* appear to be very similar in structure to the larvae of *farauti*.

In this paper, the subspecific name *farauti* will be applied to that anopheline from the New Hebrides-Solomon Islands which has become the well known and important vector of malaria and filariasis in that area. No attempt is made here to include information as to regional differences in morphology and biology.

Relation To Malaria

Accurate infectivity studies are lacking for *farauti*, but the malaria rates among military personnel stationed at bases on which this one and only anopheline is present are sufficient to incriminate it as a most efficient vector of malaria. On Guadalcanal, New Georgia, and other islands of the Upper Solomons, anopheline counts in bed nets and native huts are almost one hundred per cent *farauti*. It is by far the predominant species of anopheline taken in adult catches in the South Pacific.

On the northeast coast of Guadalcanal, typical *punctulatus* has been collected in native comps and villages but in smaller numbers than *farauti*. Although females of *punctulatus* feed readily in captivity, they do not appear to attack man often in nature. Less than one per cent of the total anophelines collected in routine night catches for a period of over a year has been *punctulatus*. This is in marked contrast to collections of *punctulatus* made in New Guinea where it is known to bite man freely in nature and is incriminated as one of the two important vectors of malaria in that area.

Relation to Filariasis

E. C. Byrd and L. S. St. Amant, working on filariasis in the New Hebrides and Lower Solomons, demonstrated that *farauti* was the only species in which the filarial larvae of *Wuchereria bancrofti*

could be found in all stages of the developmental cycle. Infective larvae (about 14 day old larvae) were demonstrated in the proboscis of wild specimens subsequently dissected in the laboratory. Considering the nocturnal periodicity of the filarial worm and its development to maturity in *farauti,* this species is apparently the only natural vector of filariasis in the area. In the New Hebrides (Espiritu Santo), the incidence of infection in *farauti* ranged up to 45 per cent. In the Solomons (Guadalcanal), the incidence of infection ranged up to 52 per cent.

Larval Breeding Sites

Buxton and Hopkins (1927) summarized their scanty dry season collections of *farauti* in the New Hebrides by saying that this species finds permanent breeding places in stagnant swamps, generally among algae. One record, which is of particular interest, was the collection of larvae in a hot spring (about 100° F.) at Whitesands, Tanna. Herivau, Roncin, and van Thai (1939), from observations on Efate, reported larval breeding in running, stagnant, clear, turbid, and brackish water, and in both shade and in full sunlight. The larvae occurred in marshes, streams, small depressions, and in such places as ditches and holes. Paine and Edwards (1929), in observations from the north coastal plain of Guadalcnal, found larvae living for the most part in very small areas of purely temporary water, such as hoofmarks, in either sunshine or shade.

These reported observations do not exhibit much uniformity, a condition that is undoubtedly due to the limited number of collections made and reported. The present summary covers almost daily records of about 40 entomologists over a period of approximately two years. No observations are available for the interior of the larger islands, all work to date having been done primarily in the low-lying coastal and inland areas.

"Dry" season breeding places for *farauti* in the New Hebrides-Solomon Islands consist primarily of rivers, streams, ponds, lagoons, flooded taro gardens, improperly constructed roadside ditches, and occasional wells near plantations or native homes. Animal wallows made in muddy flats and seepage pools formed by small springs along river banks are likely places to collect larvae at this time of the year, particularly so on the islands of Efate and Espiritu Santo. *Farauti* does not invade to any degree such habitats as undisturbed canebrake marshes. Breeding does not extend far from settled areas unless the jungle is cleared or unless remote ponds and streams have native trails leading to them. Repeated observations by entomologists who have had the opportunity to make initial surveys on newly occupied islands throughout the area indicate that *farauti* rarely

occurs in streams heavily overgrown and closed in by virgin jungle. Bodies of water isolated by broad expanses of jungle rarely yield anopheline larvae. An important factor from a military standpoint is the persistency of breeding for months after bases have been temporarily or permanently abandoned.

During the "wet" season, breeding becomes extensive in almost all the additional water collections which form. At this time, larvae may be found in all types of natural and man-made catchments. Places which may have been unsuitable for *farauti* during the "dry" season become quite favorable during periods of heavy rains. Such rains are responsible for the widespread appearance of *farauti* in catchments previously devoid of breeding. Frequent floods of large rivers and streams eliminate them as important breeding places. On Guadalcanal there is a mechanical transportation of larvae, eggs, and pupae to the flat alluvial plains of the northeastern coast due to flushing of the aquatic stages from their permanent breeding places.

Road ruts, foxholes, bomb craters, slit-trenches, and borrow-pits have been recorded as favorite breeding spots throughout the whole of the area. The concensus among entomologists in the New Hebrides-Solomon Islands is that *farauti* does not breed actively in artificial containers. Occasional reports have been made of larvae breeding in such containers as tin cans, open gasoline drums, watering troughs and tubs — especially the small wooden bath tubs used by the Japanese which were scattered throughout abandoned bivouac areas and camp sites on Guadalcanal, Munda Point, and Kolombangara. Native boats, canoes, and outriggers have been known to harbor anopheline larvae although these are not common breeding places at any time of the year.

The water in all of the above mentioned types of breeding places may be clear, turbid, somewhat stagnant, brackish, or pure rain water; water plants may or may not be present. In nearly all reported cases, breeding over extensive water areas is associated with flotage or emergent vegetation. However, over small confined breeding surfaces such as temporary pools, puddles, and road ruts without emergent vegetation, larvae are commonly found on the open surface. Animal hoofprints and other small depressions, formed around the margins of swamps, ponds, and lagoons, usually become dangerous producers of anopheline larvae. Anopheline larvae are not generally found along the margins of rapidly flowing rivers and streams without vegetation or surface obstructions.

Numerous reports have been made by casual observers that *farauti* breeds commonly in coconut shells. Repeated surveys indicate that larvae have been taken from such catchments on rare occa-

sions. Larvae have been reported occasionally from water held in the folds of felled trees and in exceptionally large tree holes, but their presence is the exception rather than the rule. Larvae have never been taken in water-filled axils of the sago palm, taro, banana, or pandanus plants; likewise, they have never been found in the axils of coconut trees, for these do not retain enough water to permit larvae to develop to maturity.

The absence of breeding in tree holes and halved coconut shells may possibly be due to rather high concentrations of decayed organic matter, or a high content of such organic compounds as dissolved tannins and vegetable oils. The absence of *farauti* breeding in tree holes and plant stem axils may possibly be due to the confinement factor coincident with oviposition in such places.

Much of the *farauti* malaria is "man-made" due to clearing operations and the resulting exposure of pools, puddles, ruts, bomb craters, shell-holes, slit-trenches, foxholes, etc., to sunlight. Repeatedly, preliminary surveys of likely breeding places have shown them to be of low endemicity before the beginning of such operations. There is a marked increase in the anopheline population soon after these areas have been opened as a result of combat operations, construction of bases, extensive logging operations, and the formation of bomb and fuel dumps. The adaptation of *farauti* breeding in places created by human activities in the New Hebrides-Solomon Islands is in keeping with the reports of *moluccensis* breeding in the New Guinea area.

The important characteristic of all breeding places of *farauti* is exposure to sunlight. Actually, this seems to be the only common factor in the habitats of the larvae, for they are to be found almost without exception on water surfaces exposed to the sun. On Espiritu Santo, larvae were occasionally found by R. G. Daggy in water on the floor of an almost totally dark concrete storage cellar. A few have been found breeding in similar shaded sites on Guadalcanal and Munda Point.

To date, it appears that the only absolute requirement for successful larval breeding is the presence of relatively quiet water. Water affected by currents, winds, or tides will support anopheline breeding only in the presence of surface obstructions. Typical obstructions are: beds of various types of water plants, floating algal mats, trailing branches, vines, roots and fallen trees. Here a sufficient amount of protection from currents, wind, and natural enemies is provided.

The presence and type of vegetation appear to be of little importance in most cases, although there are optimum conditions under

which breeding occurs most prolifically. For example, stream breeding may always be associated with growths of *Spirogyra, Lemma,* and water cress. The heaviest stream breeding will generally be found in beds of *Myriophyllum,* probably because the growth character of this plant allows the maximum amount of open, still water surface. When larvae occur in large streams or rivers, they are to be found near the banks among aquatic plants. In sunny seepages and cut-off pools along river beds, green algae grow luxuriantly and *farauti* is frequently collected.

Association With Culicines and Other Anophelines

In streams and pools *farauti* has been found in association with *Culex annulirostris* Skuse., *Culex basicinctus* Edw., *Culex fraudatrix* Theo., *Uranotaenia quadrimaculata* Paine and Edwards; and with *Bironella hollandi* Taylor, *Anopheles lungae,* B. and S., and *Anopheles punctulatus* Donitz, when these three species become flushed from their normal breeding places during the rainy season; in temporary rain-filled puddles with Aedes *funereus ornatus* Theo., *Aedes vexans* Meigen, *Culex halifaxi* Theo., and *Culex annulirostris Skuse;* in swamps and streams with *Culex squamosus* Taylor; in brackish lagoon and pools with *Culex jepsoni* Theo; and in artificial containers with *Aedes hebrideus* Edw., *Uranotaenia nigerrima* Taylor and *Culex halifaxi* Theo.

Salinity Tolerance

Present data from this area indicates that *farauti* breeds commonly in brackish water below a salinity of 70 per cent sea water. Apparently the maximum upper salinity level is somewhat about 75 per cent. In the laboratory, fourth instar larvae are known to pupate and emerge in 95 per cent sea water.

In the Tulagi-Florida Island area, where vast stretches of mangrove cover the coast line, R. E. Kuntz reported *farauti* from extensive brackish water pools high in organic debris and subject to tidal fluctuations. Anopheline larvae in all stages were found by the writer in isolated, coastal ground pools subject to tidal action.

Length of Aquatic Cycle

Laboratory studies of *farauti* have shown the aquatic cycle to average 13 to 14 days. The rearings made to date have given the following data: Egg stage, 2 to 4 days; larval stage, 9 to 10 days; pupal stage, 1 to 1½ days.

Under ideal field conditions in favorable locations on Guadalcanal, J. W. Belkin showed the aquatic cycle of *farauti* to be about 5 to 8 days. The period of egg to adult ranged from 7 to 10 days. L. D. Christenson working in the Upper Solomons demonstrated a similar fact.

There seems to be no number of definite broods or generations in nature in this area; instead, breeding is relatively continuous the year round. A reduction in breeding is well noted on Efate and Espiritu Santo during the dry season. At this time because of a general scarcity of breeding places and the absence of intermediate types of water collections, *farauti* breeding is limited to the favorite "dry" season breeding habitats.

House - Frequenting Habits

Farauti readily enters any type of shelter in search of human blood. Buxton and Hopkins (1927) collected adults from mosquito nets in the New Hebrides, and Paine and Edwards (1929) reported adults to be extremely abundant in native houses along the north coast of Guadalcanal. All reports from New Guinea emphasize the house-frequenting habits of *moluccensis,* Overbeek and Stoker (1938) even going so far as to say that it is the most important house mosquito in the territory of New Guinea. This house-frequenting habit of *farauti* has made it possible to use effectively native villages and bed nets of military personnel for adult catching stations.

Observations on Espiritu Santo by H. L. Yust indicate that after adults have taken a blood meal they have a tendency to remain in the immediate vicinity of their blood source. Collections made of engorged females resting in native huts in the early afternoon give evidence of this fact which has been confirmed by other workers on Guadalcanal and Bougainville.

Daytime Resting Places

Although the exact microclimatic specifications for the daytime resting places of adults are still quite unknown, some observations are available upon the subject.

Resting, blooded females have been collected from bed nets and sleeping quarters of military personnel throughout the area. Adult anophelines are commonly found in the thatched bamboo native huts between the levels of 2 to 7 feet.. In numerous collections made by H. L. Yust on Espiritu Santo, resting adults have occasionally been collected during the daylight hours on the stones surrounding the central fireplace and on the undersides of the crude bamboo beds in native huts. Pots, pans, bottles, jars, and other utensils scattered over the floor have been found to be excellent collecting spots for adult anophelines during the day, particularly so if these objects are in shaded corners of the huts.

L. S. St. Amant, in routine catches in native villages on Espiritu Santo and Guadalcanal, found adults resting frequently on surfaces which had a light background and upon objects which were exposed to daylight.

In nature, adults are very difficult to locate. An occasional one has been reported resting in the shaded folds of jungle trees, but unlike many anophelines, natural resting places for *farauti* have not been located.

On Efate, an adult male and female were collected resting on the face of a damp, coral-rock ledge shaded by a dense overgrowth of trees and vines. An occasional one has been collected from the protected, shaded folds of tree buttresses on Guadalcanal by J. W. Belkin and other workers. On Malo, Efate, and Espiritu Santo, adults have been collected at will from the cool and moist rock surfaces of native wells. Occasional ones have been collected resting near the water surface of sunken oil drums overgrown with jungle vines providing a cool and humid resting place.

A small windowless concrete building regularly yielded numbers of resting adults from the upper walls and ceiling.

The above reports on the resting places of *farauti* do not show much uniformity, and it is evident that detailed information is lacking relative to the requirements of this species in regard to the microclimate of its resting places. It is apparent from the numerous collections made in and around villages, plantation homes, and quarters of military personnel that *farauti* seeks by preference human habitations. Very few adults have been collected in the field away from likely blood sources.

One of the marked observations on adults made by H. L. Yust on Espiritu Santo was the general absence of female anophelines in vacated native huts, whereas occupied buildings within a few hundred yards of these abandoned quarters revealed numerous adults. Even at the height of the mosquito population, only a few isolated specimens were found in vacated huts.

Time of Activity

In numerous collections on Espiritu Santo, adults appeared at their peak between the hours of 5 P. M. and 10 P. M.; in one instance they were noted to appear in swarms about 5 P. M.; and to feed readily until 8 P. M. and 9 P. M. they were seen to disappear almost completely. In many observations of breeding areas on Guadalcanal, adults were first observed biting around 7 P. M. and continued until 11 P. M.

In the New Hebrides area, a number of records of daytime biting have been accumulated. On Espiritu Santo, L. S. St. Amant reported large numbers of *farauti* attempting to feed during daylight hours. While making routine catches from native villages during the hours 9. A. M. to 11 A. M., he reported large numbers of adults

attempting to feed upon the technicians. Many adults were collected around the ankles and legs of natives sitting in open bamboo huts.

Feeding Habits

In feeding, females are shy and wary in their approach, easily frightened away by movements, but persistent in returning to attack. Their bite is noticeably painless to many individuals. In lighted houses or tents, the anophelines attack more readily in shaded corners and on shaded portions of the body.

During many night collections on Espiritu Santo, adults were observed entering native huts flying quite low, 1 to 2 feet above the ground, and attempting to bite the ankles and thighs of native inhabitants.

J. C. Swartzwelder, who established the first colony of *farauti* in the area, demonstrated that the favorite biting spots of this species under insectary conditions were ankles, legs, and wrists. When trousers were rolled up, the back of the knee or the ankle was preferred; with the shirt off, the waist line, back and arm pits were the areas of choice.

Several observers have reported difficulty in inducing adult females of *farauti* in feed on humans in the laboratory. This would indicate the existance of more than one strain of *farauti* in the area. Although J. C. Swartbwelder and K. E. Avis encountered no particular problems in getting females to take a blood meal from either man or animals, L. E. Rozeboom, in studies from Guadalcanal, reported that females of this species refused to feed in the laboratory. Progeny of *farauti* obtained from gravid females found in native villages fed readily on man in the laboratory and deposited fertile eggs.

Host Preferences

In the New Hebrides, *farauti* has been found breeding in suitable areas where there have been no inhabitants for almost a year.

Observations by R. G. Daggy from the shores of Steaming Hill Lake, Gaua Island (Banks group) showed anopheline adults to be abundant, even though the nearest village was 5 miles away.

T. M. Floyd reported *farauti* breeding on the Russell Islands in areas where there had been no inhabitants for at least one year. A similar situation was reported from Efate and in both cases the common source of blood for the adults appeared to be that of animals, especially cattle.

On Efate, where insectary tests were used to determine the preferred host of *farauti,* other than man, J. C. Swartzwelder en-

countered no difficulty inducing this species to feed on various animals. When given a choice of animal hosts, mosquitoes preferred horses and cattle.

Light traps have been unsuccessfully used throughout the whole of the area. Modifications and new techniques in the use of traps similar to the New Jersey light trap have proved fruitless in an attempt to establish a simple, mobile, adult checking station. Constant rains, blackouts in the advance bases, variations in current output, and destruction of equipment by natives and other persons have rendered this method practically useless.

Animal traps similar to the Magoon type bait trap have been used on several occasions. The energy required in their construction, transprotation, and upkeep under conditions as existed in the New Hebrides-Solomon Islands was considerably more than most entomologists cared to expend; particularly so at a time when a control and survey program was being instituted for the sole purpose of finding and eliminating mosquitoes in as short time as possible. Light and animal bait traps have been abandoned as adult catching stations.

Flight Range and Flight Habits

No definite information is yet available on the flight range of *farauti*. Herivaux, Roncin, and van Thai (1938) stated that migratory flights of this species are very rare on Efate, the anophelines found resting in villages being derived from local breeding places. Migratory flights have never been observed in this area. Our own records show several cases of adults captured at least three-quarters of a mile from the nearest known breeding area. On Espiritu Santo, adults are commonly collected to the extent of 400 yards from likely breeding areas. A blooded female was found by R. G. Daggy on a boat anchored 600 yards off shore. On Bungana Island in the Florida group, sporadic outbreaks of anophelines occurred where the only site from which they could have originated was slightly over a half mile across the open channel. At Siota, on the northern end of Florida Island, an adult male was collected by H. W. Graves one half file away from the only known breeding area across an open channel. It is generally felt, however, that *farauti* does not fly any distance over open bodies of water unless aided by prevailing winds.

The flight of *farauti* is erratic and relatively quiet. In making adult catches, it is extremely difficult to follow mosquitoes with the beam of a flashlight due to their characteristic movement, coloration, and slender build. When disturbed by an aspirator, the adults have been noted to fly upward for almost 10 feet. This is quite differ-

ent from their usual wavy and dancing flight when they are attenpting to bite.

Mating

Mating has been observed only in the insectary. While few details are yet available, swarming was seen to occur between the hours of 8 P.M. and 10 P.M. and at an approximate height of 10 feet.

Mating has been noted in females which have not taken a blood meal although fertile eggs were not produced. A minimum of approximately tw days after emergence is required by adults before mating takes place. On Efate, Espiritu Santo, and Guadalcanal, mating has been observed in small rearing cages.

Egg Laying Habits

The eggs of *farauti* are deposited at night, although live specimens captured from native villages and subsequently introduced into cages were noted to deposit eggs during the day. The eggs when laid, are white but become black within the course of two or three hours. In the laboratory, eggs were occasionally laid directly upon a thin film of moisture over the surface of floating duckweed leaves. Gravid females readily deposit eggs when confined over damp filter paper or over pans of water.

Of eight known mated females introduced into a cage, a total of 4077 eggs were produced during an egg-laying period of 5 to 33 days. Unmated anopheline adults were introduced into a small cage and fed on fruit juices for 30 days. Eight introductions of adults totaling 166 males and 124 females were made over this period. No eggs were laid during this time. Blood meals were given to a control group on the thirty-first day and fertile eggs were laid two days later. The necessity of a blood meal to obtain fertile eggs seems apparent with this species.

On Espiritu Santo, Guadalcanal, and Bougainville, larvae were noted to appear suddenly in catchments which were still relatively moist on the bottom and the sides. These and subsequent observation by J. W. Belkin and L. O. Christenson indicate that this species will apparently lay eggs on mud, and that larvae and pupae can withstand partial drying.

A study of egg resistance to environmental conditions indicates that the period of viability of eggs exposed to direct sunlight and high ground temperatures was very brief, one day or less. However in shade and moist soil, and in the absence of surface water, eggs withstood dessication and remained viable in significant numbers for periods up to two weeks.

Longevity

Although no comprehensive data are available on the longevity of *farauti* under field conditions, five of ten unmated females fed only on fruit juices lived for 25 days in an insectary. Of adult females introduced into a humidor with the humidity kept around 85% and given blood meals regularly, some remained alive for 51 days. The average length of life of males was 12.5 days (maximum 19 days).

Acknowledgements

The material covered in this text was obtained primarily through personal communication and contact with the officers and men attached to malaria control and survey units of the U. S. Army and Navy. The author at this time wishes to express grateful acknowledgement for the valuable contributions made by these many individuals and also to the following men who aided particularly in providing information on the bionomics of *farauti* from bases throughout the New Hebrides-Solomon Islands:

Avis, K. E.	PhM 1/c USNR	Hayles, A. B.	Lt. Cdr., MC, USNR
Belkin, J.	Capt., SnC AUS	Kuntz, R.	Lt. (jg), H(S) USNR
Byrd, E. E.	Lt., H(S), USNR		
Christenson, L.	Major, SnC AUS	Oman, P. W.	Capt. SnC AUS
Daggy, R. C.	Lt., H(S) USNR	Rozeboom, L. E.	Lt., H(S) USNR
Floyd, T. M.	Lt., H(S) USNR	St. Amant, L. S.	Lt., H(S) USNR
Francelmont, J.	Capt., SnC AUS	Swartzwelder, J.C.	Major, SnC AUS
Graves, H. W.	Lt., H(S) USNR	Yust, H. L.	Lt., H(S) USNR

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MEXICO HONORS PRESIDENT OF THE NATIONAL MALARIA SOCIETY

Of particular interest to the members of the National Malaria Society is the December 1945 issue of *Revista del Instituto de Colubridad y Enfermedades Tropicales of Mexico* which carries a full-page portrait of Dr. Mark F. Boyd with the following inscription:

"The School of Public Health and Tropical Medicine pays its respects to Dr. Mark F. Boyd, as it has to many other prominent Malariologists, for his valuable, original, learned and wise studies in connection with the control of malaria.

The Director."

Malaria Research in the U. S. Public Health Service

Malaria research is carried on by two divisions of the National Institute of Health. The Division of Infectious Diseases operates the Office of Malaria Investigations, with headquarters at Memphis, Tennessee (Dr. V. H. Haas), and another laboratory at Columbia, South Carolina (Dr. M. D. Young). The Division of Physiology maintains a malaria laboratory at Bethesda, Maryland (Dr. G. R. Coatney).

The laboratory at Memphis is engaged primarily in attempts to produce artificial immunity in experimental malaria. Studies include methods of modifying the parasite, and various investigations on the exo-erythrocytic stages. *Plasmodium gallinaceum* is maintained in chickens, chick embryos, and *Aedes aegypti; P. cynomolgi* is maintained in monkeys, chiefly by blood inoculation, but also by sprozoites in *Anopheles quadrimaculatus* as occasion requires. Considerable work has been carried on in the past with DDT as a residual spray to control *A. quadrimaculatus,* but investigations with this compound are now limited to experiments dealing with its use as a larvicide.

The Columbia laboratory conducts investigations on human malarias, dealing with parasitology in man and mosquito, immunology, host-parasite relations, and transmission by mosquitoes under varying conditions. Detailed cytological studies on the parasite are being carried out. *Plasmodium vivax* is maintained in the form of the St. Elizabeth strain and several foreign strains, including the Chesson and the Pait. The U.S.P.H.S. strain of *P. malariae* is maintained, and the McLendon and Santee-Cooper strains of *P. falciparum.* All are available as sporozoite infections, regularly with *Anopheles quadrimaculatus, A. punctipennis* and *A. maculipennis freeborni,* and seasonally with other anophelines. Infected mosquitoes are routinely supplied to the malaria laboratory of the Division of Physiology for drug testing.

The Division of Physiology is concerned with screening and testing of antimalarial drugs, against *Plasmodium gallinaceum* in chickens (using both sporozoite-induced and blood-inoculated infections) and against human malarias. The McLendon strain of *P. falciparum* and the St. Elizabeth and Chesson strains of *P. vivax* are employed; all are available as sporozoites in *A. quadrimaculatus.* Concurrently with drug testing, investigations are being conducted on the biology of *P. gallinaceum* and the human parasites, including studies on the course of infection, aspects of immunity, and pathology (in chicks). Studies on the biology and host-parasite relationships in the various mosquitoes used as vectors are also carried out.

The Division of States Relations of the Public Health Service is engaged in widespread malaria control operatons, and certain related investigational projects are being carried out, but these are of a type that do not come within the scope of the Committee on Medical Research.

Squibb Institute, New Brunswick, N. J.

(Dr. Arthur P. Richardson)

The principal lines of investigation have been concerned with antimalarial drugs. Screening of various compounds for activity, standardization of tests, and pharmacological studies preliminary to clinical trials of drugs are being carried out.

ENTOMOLOGICAL EVALUATION OF DDT RESIDUAL SPRAYING FOR MALARIA CONTROL[1]

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U. S. Public Health Service, Atlanta, Georgia

(Received for Publication 13 November 1945)

During 1945 the office of Malaria Control in War Areas of the U. S. Public Health Service in cooperation with health departments of the states concerned initiated what has been termed the Extended Program for malaria control. This program is designed to reduce malaria in the more important endemic areas of the southeast and to meet the threat of increased malaria transmission occasioned by the return of troops. As a part of this program some 400,000 residences have been treated with one or more applications of DDT residual spray. Only occupied houses, together with outdoor privies were treated.

The spray used was a xylene-triton-water emulsion containing 2½ per cent DDT which was applied at the rate of 100 mgs. of DDT per sq. ft. Every effort was made to obtain intelligent and uniform spray applications; training courses for supervisory personnel and foremen were held and detailed instructions were issued to all workers. It is believed, therefore, that the results of this work, while perhaps not altogether comparable to those obtainable by experimental methods, are representative of what may be expected when DDT becomes generally available for this work.

Indexes to the effectiveness of this widespread work were obtained in two ways:

1. Inspections of a small percentage of treated houses selected at random were made at intervals after spraying to determine results of the spray in keeping houses free of *A. quadrimaculatus*.
2. Precipitin tests were made of blood from *quadrimaculatus* stomachs collected around sprayed and unsprayed premises to determine the human blood meal rates. This method of checking results of spraying was planned since it was conjectured that if *quadrimaculatus* feeds principally on humans while indoors, as is commonly supposed, and these human feeders are being killed by resting on the sprayed surfaces, the general *quadrimaculatus* population about the sprayed premises should show a low human feeding rate in comparison to that obtained in unsprayed areas.

[1] Presented at the meeting of the National Malaria Society, Cincinnati, Ohio, 13 November 1945.

Table 1 summarizes records of house inspections received to date. It shows that a total of 9,949 inspections have been reported

Table 1.—Total houses inspected and per cent in which *A. quadrimaculatus* was found during afternoon inspections.

Months following spraying	Number of houses inspected	Houses with *A. quadrimaculatus*	
		Number	Per cent
Less than 1	3225	38	1.2
1 - 2	3399	69	2.0
2 - 3	2337	112	4.8
3 - 4	774	38	4.9
4 - 5	214	18	8.4
Totals	9949	276	
Per cent			2.8

and that these were made at intervals following spraying varying from less than 1 month to a maximum of over 4 months. Two hundred and seventy-six sprayed houses, or an overall percentage of only 2.8 of those houses inspected contained *quadrimaculatus* during the afternoon. It will be noted that there is a gradual decrease in the effectiveness of the DDT deposits at successive monthly intervals after application. Inspections made less than one month after spraying indicated that 1.2 per cent of the treated houses were positive for *quadirmaculatus*. This percentage increased to 2.0, 4.8, 4.9 and 8.4 after intervals of 1, 2, 3, and 4 months respectively. The small number of inspections of houses made 3 or more months after spraying is due to the spraying schedule established, which called for re-spraying at 3 months intervals.

In Table 2 the inspection records are grouped to show the effect of age of deposit and numbers of *quadrimaculatus* in outbuildings on the per cent of *quadrimaculatus* positive houses. Only those houses which contained mosquitoes in the afternoon are considered as positive. These data show that in general for all spray ages the greater the density of *quadrimaculatus* around the premises, the greater is the percentage of sprayed houses positive for mosquitoes. It is considered that these data merely indicate that greater numbers of mosquitoes enter houses in areas of high densities and therefore there is a greater chance that some will find non-lethal resting places. This

table also shows, although with considerable irregularity, that the decrease in spray effectiveness with age occurs in each density group except the first. In this group the low density of mosquitoes on the premises accounts for this apparent uniformity.

In order to fit the inspection routines into usual working hours, inspections were made throughout the day. However, houses in which *quadrimaculatus* were found during morning inspections were re-inspected during the afternoon. This procedure necessitated 356 afternoon re-inspections at which 74.4 per cent of the morning-positive houses were found to be free of mosquitoes.

Table 2.—Effect of premise densities and age of spray on percentage of *quadrimaculatus* positive houses (afternoon inspections).

Months following spraying	Natural Resting Place *quadrimaculatus* Densities						All
	0—10	11—50	51—100	101-200	201-400	400+	
	Per Cent of Positive Inside House Inspections (afternoon)						
Less than 1	0.7	1.5	2.5	1.5	1.0	6.5	1.2
1 - 2	1.0	2.9	5.1	3.7	3.2	6.8	2.0
2 - 3	1.8	4.3	6.9	11.5	12.7	37.7	4.8
3 - 4	1.1	7.3	5.4	18.9	16.0	55.5	4.9
4 - 5	1.5	10.4	0	11.7	85.7	66.7	8.4

Table 3.—Reduction in houses positive for *A. quadrimaculatus* from morning to afternoon.

Months following spraying	Number of houses with *A. quadrimaculatus*		Per cent reduction
	Morning	Afternoon	
Less than 1	51	4	92.2
1 - 2	96	10	89.6
2 - 3	144	44	69.4
3 - 4	47	20	57.4
4 - 5	18	13	27.7
Totals	356	91	
Per Cent			74.4

Table 3 summarizes the records of these re-inspections. A gradual lessening of toxicity of the spray is indicated by the decreasing percentage of houses which became mosquito free by afternoon at successive monthly intervals after spraying, that is, as the DDT deposits aged. When inspections were made less than 1 month following spraying, 92.2 per cent of the morning-positive houses were found to be free of live mosquitoes in the afternoon. This percentage decreased to 89.6, 69.4, 57.4 and 27.7 for inspections made 1, 2, 3, and 4 months respectively after spraying.

Table 4 shows for those houses found positive at morning inspections the decrease in numbers of *quadrimaculatus* which occurred between morning and afternoon at successive monthly intervals. As in Table 3, a lessening of effectiveness of the spray with age is shown.

Only a relatively small per cent of the total samples of *quadrimaculatus* bloods taken for determination of human feedings have as yet been tested. However, of 4,518 specimens collected on premises where the houses had been sprayed only 0.44 per cent gave human reactions while 3,784 specimens from unsprayed premises gave a human feeding rate of approximately 3.0 per cent. It is believed that these data which show 85 per cent fewer *quardimaculatus* with human feedings about the sprayed premises are highly significant as indicating a lessened hazard of malaria transmission.

Table 4.—Reduction in numbers of *A. quadrimaculatus* in houses from morning to afternoon.

Months following spraying	Total *A. quadrimaculatus* in houses		Per cent reduction
	Morning	Afternoon	
Less than 1	156	6	96.2
1 - 2	241	19	92.1
2 - 3	472	149	68.4
3 - 4	121	39	67.8
4 - 5	51	29	43.1
Totals	1041	242	
Per Cent			76.8

Summary

1. Residual deposits of DDT were applied to some 400,000 homes for control of malaria during 1945.

2. Such deposits were highly effective in keeping houses free of resting anopheline mosquitoes.

3. Effectiveness of DDT deposits, as measured by the percentage of sprayed houses found free of live mosquitoes, gradually decreased during successive months following application. However, after 4 months live mosquitoes were found in only about eight per cent of treated houses examined.

4. There was an apparent reduction of 85 per cent in the number of *quadrimaculatus* mosquitoes which had human blood meals in sprayed areas as compared to unsprayed areas.

HENDERSON GOES TO COLUMBIA

John M. Henderson, formerly Chief, Engineering Division of Malaria Control in War Areas at Atlanta, Ga., is now resident Professor of Sanitary Science at the School of Public Health, Columbia University, New York.

S. A. Sanitary Engineer Frank Tetzlatt has been assigned to Prof. Henderson's former position with MCWA or, as now designated, Communicable Disease Center.

The Principles and Practice of Tropical Medicine

By L. Everard Napier, Illus., 917 pages, Macmillan Co., New York, 1946

Price $11.00

The appearance in recent years of a bewildering number of manuals or texts of tropicial medicine, reflects the currently enhanced attention given this field. The present attractively produced volume is contributed by a clinician and teacher with extensive experience in British India, and conseqently exhibits a bacgkround arather unusual in a characteristic American imprint. Anyone assuming the responsibility for a manual in this field inevitably acquires a serious inital handicap, as the opinion seems to be general, probably arising because the tropics constitute a belt around the world, that treatment of the subject must be from a global standpoint, an attitude which immediately expands the scope of the subject beyond the radius of serious individual experience.

Our author's concept of tropical medicine is revealed by the cir cumstance that of the 860 odd pages of text, about 700 are devoted to a consideration of infectious diseases, and this despite omission of any consideration of typhoid fever, tuberculosis and smallpox. About 80 pages deal with malaria and blackwater fever, about 30 to the fevers of the typhus group, and about 20 to uncinariasis. Insofar as malaria is concerned, it has received attention proportionate to its importance, but one is struck by the limitation of the presentation of mycoses, to the superficial cutaneous infections. About 90 pages are devoted to nutritional disorders and about 50 to the effects of tropical climate. Notwithstanding that the work is essentially a treatise on infectious diseses, a field in which laboratory aid is of paramount importance in reaching a diagnosis, the laboratory procedures described are of the simplest character.

Limiting critical appraisal to the circumscribed field with which the reviewer is personally conversant, there are noted comparatively few points to which exception might be taken, and fewer still where factual statements migh tbe challenged, while significant recent work has been given proper recognition.—Mark F. Boyd.

APPARENT ANOMALIES IN THE BEHAVIOR OF ANOPHELINE MOSQUITOES IN SOUTHWESTERN GEORGIA

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(Received for publication 1 May 1946)

A wealth of information on specific aquatic environments for the Nearctic species of anophelines occurring in the United States has been contributed by numerous investigators, and while it is probable that deviations from the norm are familiar to the more experienced field workers, it appears to the writer that information on the unusual or extreme conditions under which anopheline breeding may transpire has not been adequately recorded. For this reason, it seems desirable to publish observations which indicate that there may be, at times, considerable flexibility in the range of habitat tolerance associated with our domestic anophelines. In publishing these observations, there is no intention to imply that generalizations on specific environments are not useful, but we feel that exceptions as well as generalizations should be noted for the benefit of the many workers with little or no biological background and scanty field experience who are at present engaged in entomological activities, and who, in the words of Dr. Justin M. Andrews, "will probably continue to be engaged in such work for some time to come".

Favorable and optimum conditions for the production of *Anopheles quadrimaculatus* have been variously defined as open, sunlit, or partially shaded aquatic situations containing profuse emergent or floating vegetation, or non-vital flotage of a character which might provide food and cover for the larvae, and with an alkaline to slightly acid pH range. Gross pollution with sewage or industrial wastes, and salinity, inhibit or prevent larval development. Similar conditions are suitable for the production of *Anopheles punctipennis*, while *Anopheles crucians* is more tolerant of relative acidity. Both permanent and temporary, quiet and slow-moving waters are utilized. (Boyd, 1930; Bradley and King, 1941; Watson and Hewitt, 1941). Little reference is made to breeding in artificial receptacles.

Most county malaria control organizations with whom we have worked consider natural aquatic environments and artificial impoundments which approach the "optimum or favorable" conditions

*Presented at the annual meeting of the Association of Southeastern Biologists in Columbia, South Carolina, April 19, 1946.

outlined above as the only important production areas for anophelines. However, we have found anopheline larvae, sometimes only a few, but occasionally ranging into the hundreds in number, in such unusual receptacles as stock watering troughs, rain barrels, a concrete mixer, bird baths, poultry watering troughs, and large tin cans. Dr. Paul C. Beaver informed us that he collected significant numbers of *A. quadrimaculatus* larvae from a pool near Waycross, Georgia, which was grossly polluted by the effluent from a broken sewer. In some instances, large numbers of *A. quadrimaculatus* larvae, in all stages of development, were found in these places adjacent to unprotected human populations. The production of large numbers of adult anophelines from numerous natural breeding ponds in the area under consideration prevents the formation of even a rough estimate of the total emergence of adults from a typical situations. However, it is well known that a small breeding area can produce relatively large numbers of anophelines. Goldfish pools in cities are notorious offenders.

The hydrogen ion concentration of water has received consideration as a possible modifying influence on the breeding proclivities of anophelines. Bradley and King (1941), in quoting Boyd (1929), state that *A. quadrimaculatus* and *A. punctipennis* have never been found in Georgia and North Carolina in waters having a pH value below 5.1, and that *A. crucians* is never found in water which is more acid than pH 4.6 nor more alkaline than pH 8.0. Mayne (1926), however, found *A. crucians* breeding extensively in the very acid waters of the Okefenokee Swamp. Legwen and Kirby (1939) considered hydrogen ion concentration as a more or less reliable index for the application of control measures in Richmond County, Georgia. However, the author has repeatedly found a significant amount of anopheline breeding in waters which would, if such an index be the criterion, be considered of an acidity exceeding that usually tolerated by the species in question. Bradley and King (1941) point out that pH readings may vary considerably within the same pond, and also at different times of the day.

During the summer of 1944, in Wilcox County, larvae of *A. quadrimaculatus* were collected in varying numbers from each of five ponds with hydrogen ion concentrations ranging from pH 4.8 to pH 5.0 in the larval micro-habitat. Two of the ponds supported extensive breeding. In the course of the same investigation, larvae of *A. crucians* were taken from one pond with a pH value of 4.0 in the larval environment. Investigations in Dougherty County, also in the summer of 1944, paralleled the observations in Wilcox County. A few larvae (one or two per 50 sweeps) of *A. quadri-*

maculatus were found in each of two ponds with hydrogen ion concentrations of 4.0 and 4.5, respectively, and larvae of *A. crucians* were collected from each of six different ponds with pH values of 4.0, 4.0, 4.0, 4.1, 4.5, 4.5, and from one pond with a hydrogen ion concentration of 8.9. On May 28, 1945, large numbers (from two to eight per sweep with a dipping pan measuring 10 x 14 inches) of larvae of both *A. quadrimaculatus* and *A. punctipennis* were collected from a pond in Crisp County which contained relatively acid water of pH 4.8.

The hydrogen ion concentrations were measured at varying times of the day, by means of a Hellige comparator, and in each instance determinations were made in the field on samples from the larval micro-habitat, which is, as Boyd (1930) points out, the environment to which the larvae are actually exposed. Inasmuch as the feasibility of employing hydrogen ion determinations made directly on samples from the breeding areas, for an index of suitable larval environments is here alone in question, no consideration is given to the relative merits of this method as compared to the technique of residual pH.

Collections of larvae from "unorthodox" environments represented less than one per cent of the total collections, and would ordinarily be viewed with more academic interest than concern in a program of malaria control. However, the presence of larvae in considerable numbers, and in several different instars would indicate, according to Boyd (1930), that the breeding places are frequented repeatedly by the female anophelines for the purpose of oviposition, and where sufficient breeding occurs in proximity to unprotected human hosts, such situations may merit attention.

While most anopheline breeding actually does occur within the limits generally described as "optimum", it is to be noted that, in certain instances, significant breeding of malaria vectors may occur in situations which, by these criteria, would be considered unfavorable. Such instances would seem to indicate that, while in a large number of cases it may be possible to employ other than biological procedures for a determination of the relative innocuousness or inimicalness of anopheline breeding areas, there are important exceptions which preclude absolute reliance upon such methods, and which emphasize the necessity for biological evaluation of any area for which a control program is planned. The foregoing observations have led the writer to conclude that the hydrogen ion index, as applied to malaria control, should be employed as a supplement, and not as a substitute, for entomological investigations, and to conclude further that clear-cut delineation of optimum breeding areas is most difficult.

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A MALARIOLOGIST IN MANY LANDS

Marshall A. Barber

University of Kansas Press, Kansas City, Kansas

In this brief (153 pages) chronological account of his extensive experiences in anti-malaria pioneering, Dr. Barber has combined personal anecdotes, historical references, and scientific expositions in a manner that is both interesting and informative. The style is essentially narrative, and the language is simple and lucid; technical terminology has been largely avoided, and has been clearly explained in the few instances where it has been used.

Dr. Barber discusses the varying aspects of malaria in the many lands where he has worked during a long and distinguished career. His point of view is an unusually comprehensive one, embracing all the features of what is still the world's commonest disease: history, epidemiology, entomology, parasitology, and control. The malariologist will find it a stimulating presentation, and to the reader whoes main interests are in other fields of public health this little book offers an interesting and readily intelligible view of malariology.

The anecdotal and background material are sufficiently interesting to cause the reviewer to feel regret that the volume is as short as it is. It is hoped that Dr. Barber may find it practicable to give us some more of his experiences in the near future. —Victor H. Haas.

EXPERIMENTAL TRANSMISSION OF *P. FALCIPARUM* BY *ANOPHELES MACULIPENNIS FREEBORNI*

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Office of Malaria Investigations, Columbia, S. C.

(Received for publication 12 April 1945)

Anopheles maculipennis freeborni is generally accepted, on epidemiological grounds, as the principal vector of malaria on the west coast of the United States. It has been pointed out previously (Moore, Young, Hardman, and Stubbs, 1945) that no information has been found on its ability to transmit *Plasmodium falciparum*. We now report such a transmission.

The mosquitoes used were from a colony (F-1 strain) established from adults taken at Marysville, California (Hardman, 1946; Moore, et al. 1945). The malaria was the McLendon strain of *P. falciparum* isolated from a South Carolina negro in 1940 (Young, McLendon, and Smarr, 1943) which since has been used continuously for the treatment of neurosyphilis.

A. quadrimaculatus were used simultaneously as controls. The donor patient infecting the mosquitoes was a negro in whom malaria had been induced by a blood transfer. The two species of mosquitoes were fed upon the donor patient March 8, 1946, at which time there were 95.2 gametocytes per cmm. No exflagellation of male gametocytes was seen. The mosquitoes were kept after feeding at 75 degrees F.

Twenty-one days after the infective blood meal, the infected mosquitoes were fed upon neurosyphilitic patients. The comparative data on the mosquito infections and transmission results follow:

	A. quadrimaculatus	*A. m. freeborni*
Mosquitoes dissected	29	30
Mosquitoes infected	21	21
Oocysts pre infected gut, average	9	11
Sporozoites per gland, average*	++	+++
Recipient patients inoculated	1	2
Infected mosquitoes biting recipients	5	4
Patients developing infection	1	2
Prepatent period — Days	15	15; 29
Incubation period — Days	12	18; 32

* Intensity of sporozoites grouped as follows: 10—99 = ++; 100—999 = +++

Compared to *A. quadrimaculauts, A. m. freeborni* showed a slightly lower rate of infection but the individual infected specimens showed a higher intensity of oocysts and sporozoites. The pre-

patent periods in the patient infected by *A. quadrimaculatus* and one of the patients infected by *A. m. freeborni* were the same (15 days). The lengthened prepatent period in the second patient (29 days) infected by *A. m. freeborni* may have been due to partial immunity.

To our knowledge, this is the second human plasmodium experimentally transmitted by *A. m. freeborni*. The other was *P. vivax* of foreign origin (Moore, et al. 1945).

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THREE NEW ANOPHELINE RECORDS FROM NEW GUINEA

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(Received for publication 29 April 1946)

Anopheles karwari (James)

Although widely distributed in the Oriental Region, this species has not previously been recorded with certainty from New Guinea or elsewhere in the Australasian Region. Its nearest point of occurrence as recorded by Swellengrebel and Rodenwaldt (1932 p. 188), was in western Celebes, and these authors mention it (p. 85) as "doubtfully found in New Guinea." The finding of the species in considerable numbers at Hollandia, in northern New Guinea, during 1945, is, therefore, of interest.

The first specimen collected by the present writers was obtained on January 20, 1945, when one female was identified in a light-trap collection from a large rain-forest clearing about two miles east of Lake Setani. At the same time we were informed by K. L. Knight and L. E. Rozeboom of their capture of a single female the previous day at a location about fourteen miles away. On March 16, a few larval specimens of *karwari* were brought to our laboratory by W. A. Shelton and a subsequent investigation of the location from which they were obtained showed a heavy infestation of adults of the species. The writers are indebted to Sergeant Shelton for assistance in the observations on its habits reported below.

The area was a rolling plateau about four miles north of the eastern end of Lake Sentani, at an elevation of about 500 feet. Beginning about 200 yards from a small military camp (the 161st Photo Signal Laboratory) was a treeless, grassy bog about a half mile long by a quarter mile wide largely covered with water a few inches deep. This bog was judged to be the principal source of large numbers of *A. karwari* adults that were found around the camp, but, unfortunately for purposes of study, was being treated with oil for anopheline control. Larvae were to be found only in pockets that had been missed by the spraying crews and most of these larvae were small. Difficulty was experienced in rearing this species to the fourth instar or to the adult stage for identification. During the period from March 16 to May 6, a total of 134 anopheline larvae and pupae were obtained by dipping over the area, of which 29

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fourth instars and 25 reared adults (14 males and 11 females) were identified as *karwari*. There were taken in sunlit wheels ruts along the edge of the bog, in shell holes, and in natural depressions, all with clear water. A few more were also obtained in the shallow water in the bog around grass stems and pitcher plants. Agitation and muddying of the water in the wheel ruts brought more larvae to the surface than could be obtained by collecting from the undisturbed water. Although these unshaded waters appeared favorable for the breeding of the subspecies of *A. punctulatus*, only four larvae of *A. p. farauti* were taken on one occasion from a natural grassy pool.

In April, several foxholes were dug in the field for study and were left unsprayed. During the first two weeks about 55 anopheline larvae, mostly small, were collected from these holes, and three females of *A. karwari*, one female of *A. p. farauti*, and one male of *A. p. punctulatus* were reared from these. The third week about 50 larvae were taken, all of which were identified as *A. p. punctulatus*.

Besides the anophelines, larvae of *Culex whitmorei* were taken in the pools of the bog and were sometimes the only species present. *Culex halifaxi*, *C. pullus*, and a species of the *C. vishnui* group were also taken on occasion.

At the military camp about 200 yards from the edge of the bog, numerous adults of *karwari* were found at night in lighted tents on almost all inspections made by Sergeant Shelton during the period of investigation from March to June. As many as 116 were collected in one tent between 7:30 and 8:30 p. m., 85 another night between 9:30 and 10:30, and 89 on a third night between 6:30 and 8:00. Except for a single male, all adults were females. They began entering the tents when the lights were turned on at dusk (about 5:50 p. m.) and seemed to reach a maximum soon afterwards. Heavy winds at this time reduced the numbers entering the tents but light rains apparently did not. The females seemed to be strongly attracted to lights as they rested immobile on the tent walls nearest the lights and moved reluctantly when disturbed. They were noticed to disperse when the lights were turned off. During one night when observations were made in one tent at varying intervals, 25 adults were counted on the tent walls at 6:25, 56 at 6:40, 47 at 7:20, 94 at 8:15, 20 at 10:35, and 10 at 10:50. After the lights had been turned off at 11:00, 7 were counted in the tent at 11:15, 20 at 11:55, 2 at 12:10, 5 at 2:00 a. m., and 2 at 4:00 a. m. Most of the specimens noted after the tent was darkened were resting on mosquito nets covering several sleeping men. During the daytime, very few resting *karwari* could be found in any of the tents.

That *A. karwari* is a rather silent and painless biter is indicated by the discrepancies between the statements of the men living in these tents and observations of the mosquito's biting habits. The men maintained that they were not bothered by mosquito bites in the evening, although several spoke of small welts which were attributed to such bites. From personal observation, Sergeant Shelton reported that the females bit quite readily but were wary and easily disturbed. During the evening referred to in the preceding paragraph, with several men sitting around in their shorts, 14 bites were recorded between 5:45 and 11:05 p.m. On another night, eight bites were noted during the same period. When the lights were turned out, biting activity increased. Most of the biting occured about the ankles. Examination of mosquito nets after the men had retired sometimes showed females attempting to bite parts of the body touching the nets. In a few attempts to feed specimens, both wild-caught and reared, placed in cages, none could be induced to bite.

A. karwari has not been recorded in the literature as a natural vector of malaria although laboratory infection of the species has been reported. In dissections of 119 females from the location mentioned above, none was found to harbor malaria parasites (Toffaleti and King, 1946, in ms.).

Anopheles lungae (Belkin and Schlosser, 1944)

This species, which was recently described from Guadalcanal in the Solomon Islands, was taken at Hollandia by the junior author and Staff Sgt. Walter Christ in May, 1945. Larvae were found in a few densely shaded, muddy hog wallows in a sago swamp near Poee village on the south side of Lake Sentani, and adults were reared from them. Sixteen larvae were taken the first time, but none was found on four subsequent visits. On the fifth visit two larvae were taken under conditions similar to the above. In the pools at the time of the first visit were larvae of a species of Aedes (*Aedes*). Taken with the last collection were specimens of *Bironella gracilis* and a species of *Culex* (*Lophoceraomyia*). No adults of *lungae* were taken in houses in the native village about 200 yards from the breeding place, although large numbers of *Anopheles punctulatus punctulatus, A. p. farauti,* and their intermediate forms were present in the houses. Morphologically, both the adults and larvae are very similar to the species as described by Belkin and Schlosser and to specimens sent by them to the present writers from the type locality. Minor differences noted were that in our material the white ring at the tip of palpal segment 3 in the female is about twice as long as in the Guadalcanal specimens, and hair 11 of the larval

propleural group is single in some specimens and branched from 2 to 4 times in others, instead of having from 3 to 5 branches as described for *lungae*. These differences seem too slight to warrant separation of the two as possible subspecies without having larger series for comparison.

Anopheles punctulatus ?var.

One female of what appeared to be a new variety of the *punctulatus* series of *Anopheles* was obtained in a light-trap collection on the night of April 19, 1945. The trap was operated at the edge of a rain forest a few hundred yards from the location at which the first specimen of *A. karwari* was taken. The writers are informed that a specimen of possibly the same form was collected in another area at Hollandia by members of a Naval malaria control unit recently described as *A. clowi* by Rozeboom and Knight (1946).

The palpus of our specimen is typical of the *punctulatus* series in having a pale ring followed by a narrow dark ring on the apical half of segment 3. The proboscis resembles that of some specimens of the "intermediate" form in having an elongate, pale-scaled spot ventrally on the apical third of the labium. The most apparent difference from other forms of this group occurs in the markings of the tarsi, the last four segments of the fore and mid tarsi and the last three of the hind tarsi being entirely yellowish-scaled except for narrow basal dark rings on each segment and an additional small dark spot sub-bassally on segments 2 or 3 in some cases. While the tarsal pale scaling varies considerably in other forms of this group, it seems to be more extensive in this specimen than in the extremes previously noted in the other forms. The wing fringe has a longer pale-scaled area, which extends from the tip of vein 5.1 to the tip of the anal vein. The spotting of the wing veins appears rather typical of the group and vein 1 has about twelve dark spots, two of which are based of the presector dark area.

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PROGRESS IN THE DEVELOPMENT OF MALARIA CONTROL TECHNIQUES[1]

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(Received for publication 14 November 1945)

Progress in the development of any science is usually a long chain of events extending into the distant past. Modern malaria control began less than 50 years ago with Ronald Ross' discovery of the complete life cycle of a malaria parasite. The present discussion will be limited, however, to developments which have occurred since the outbreak of the recent war. Progress has been made in the development of new materials, equipment, and methods, and has extended throughout the various professional fields concerned in malaria control.

The use of new or recently developed drugs and the standardization of procedures for their effective use in the mass treatment and prevention of malaria is a subject deserving of lengthy discussion. This phase of the work shall be left to those more versed in that field and this discussion shall be confined to progress made in malaria suppression by vector control.

The outstanding innovation in malaria control is conceded by most to be the introduction of DDT (dichloro diphenyl trichloroethane) as an insecticide. Certainly this discovery will go down in the annals of scientific history as a war-time development of the first magnitude. It extends the scope of malaria control far beyond its former limitations. Suppression of this disease can now be undertaken on a greatly enlarged scale and at a moderate cost. Such an undertaking will, it is hoped, be the inevitable result once the material is abundantly available, and in the hands of an enlightened public.

DDT as a Residual Spray

It is now known that the homes of all individuals can be rendered practically mosquito free by the proper application of DDT. This insecticide has the remarkable and fortunate property of retaining its lethal effect for some time after it is applied. When applied to the interior surfaces of buildings at the rate of 200 mg. DDT per square foot, most anopheline mosquitoes which enter receive a fatal dose from treated surfaces. The chances of a mosquito biting a infected individual, surviving the 11 days necessary to develop the

[1]Presented at the annual meeting of the National Malaria Society, Cincinnati, Ohio, 14 November 1945.

parasite and biting another individual, in a community of treated homes, would appear to be extremely small.

Many questions regarding DDT are still unanswered. One of the most commonly asked is, how long will a single DDT treatment be effective in malaria control? This question has not been answered, and we doubt seriously if it will. The proportion of mosquitoes that need to be killed to effect satisfactory malaria control depends upon the endemicity of the disease, the human host density, and the natural vector population. If these conditions are favorable to malaria transmission a kill of 80 per cent or more of all mosquitoes entering treated buildings might be insufficient for adequate protection. In areas of low endemicity with sparse vector and human popultaions a kill of 5 or 10 per cent might be sufficient to break the chain of transmission. This is only a suggestion of the difficulty of predicting the effective duration of adequate DDT residual spraying in malaria control. The type of surface on which the spray is applied affects its duration, and surfaces vary from building to building. Temperature, sunlight, humidity and varying meterological conditions in general are other factors which may affect residual duration in different localities.

On the Extended Malaria Control Program of the U. S. Public Health Service, a spraying cycle of three months is used. Absolute proof of the wisdom of this choice can be found only in future records of the incidence of malaria before and after treatment. From a theoretical entomological point of view, malaria control is attained upon elimination of the vector, and proof of results with a reduction less than this depends upon comparative malaria incidence data. Certainly, however, a feasible guide to malaria control is present in entomological data. That the remarkable reduction in vectors in treated areas would result in reduced malaria is reasonable, since the incidence of malaria is surely a function of the vector population.

Insufficient data are now available to justify the classification of DDT residual house spraying as a malaria panacea. Its efficacy as a control measure in residence spraying is based upon the assumption that a great majority of the mosquito bites in the malaria transmission chain occur within or about the home. If such is needed the case, extinction may not be too difficult. If, however, a sizeable proportion of human host bites occur outside residual spraying zones the elimination of malaria will be more difficult, but DDT will be a potent weapon in the attack.

The Public Health Service treated some 300,000 homes during the past season and excellent control of *Anopheles quadrimaculatus* within these homes was obtained over a three months period in most instances.

In many cases apparently adequate protection beyond this period could have been obtained; in others some trouble from biting mosquitoes began before retreatment.

In laboratory tests with *A. quadrimaculatus* at a 60 minute exposure to wood surfaces treated with 200 mgs. DDT per sq. ft., a 70 per cent kill was obtained three months after treatment, and a 55 per cent kill one year after treatment. In treated occupied houses loss of toxicity is more accelerated, but, based on numerous and diversified tests, together with practical field observations, a three months treatment cycle, although not proper in all instances, appears, in general, to be a feasible compromise.

DDT as a Larvicide

As a larvicide DDT is as effective as anything we have tested, and the ease of application and reduced cost are factors in its favor. One-tenth pound of DDT in one gallon of oil can be applied manually at a material cost of 13 cents per acre, based on recent prices, as compared to $1.60 per acre for oiling, and 26 cents for paris green.

Large open bodies of shallow water have been covered manually in one-third of the time required with either paris green or fuel oil. A saving of 25 per cent in time required for actual larviciding is a conservative estimate for routine treatment.

DDT is effective against all larval instars and thus, under favorable conditions would permit a longer larviciding cycle.

One per cent DDT dust applied at a nominal rate of 0.1 lb. DDT per acre in 21 tests gave a 24 hour kill of 83 per cent for first and second stage larvae and 90 per cent for third and fourth stage. With 0.1 lb. DDT applied in 1 gal. fuel oil per acre a 97 per cent 24 hour kill of all instars was obtained in 10 tests, and reinfestation after one week was considerably less than with DDT dust or paris green. Ten per cent paris green dust applied at the rate of 1 lb. paris green per acre gave results in 24 tests comparable to the DDT dust, which was inferior to the DDT spray. These results are from a regular malaria control operational program extending over a season's work. DDT has produced some kill of fish in small bodies of shallow water at 0.1 pound per acre after repeated routine treatments. The significance of this can be determined only after further tests, and analyses of data on hand. At a dosage of 0.05 lbs. per acre very little damage to biota occurred, good larval kills were obtained, and this is the dosage currently recommended. In general the formulation of an effective larvicidal dosage of DDT that is acceptable to conservational interest does not appear too difficult.

The use of a fog spray of a DDT solution removes the necessity for much of the clearing now necessary as an adjunct to conven-

tional larviciding. Such a larvicide can penetrate dense foliage and when applied with an effective spreading agent, will surround the protecting vegetation, which so often harbors mosquito larvae, and make possible a more effective kill under difficult conditions.

Development of Equipment

The introduction of DDT and the necessity for malaria control under diverse war time conditions has resulted in the devising and modifying of insecticide dispersing equipment to meet new demands. A noteworthy development has been equipment for the dispersion of space insecticide aerosols. Aerosol bombs utilizing dichlorodifluoromethane (Freon 12) as a propelling agent have permitted the instantaneous killing of malaria vectors in barracks, tents, and foxholes, and will certainly be a potent future factor for malaria control in the home.

The use of hot gases from the exhaust of aircraft and ground vehicles and the dispersal of DDT sprays and dusts from airplanes has made possible the disinsectization of bivouac and even combat areas prior to the entrance of troops. Larviciding by the use of airplane dispersed thermoaerosols has been developed to a high degree, and this is considered to be one of the fastest and cheapest methods for area control on impounded waters.

The army M-2 smoke generator has been converted for dispersal of DDT aerosols. Here small particles of DDT are dispersed in steam to destroy effectively vectors over large areas.

The large scale residual spraying by the Public Health Service necessitated the development of mechanical power mixing equipment. A mixer capable of preparing sufficient DDT concentrate for 650 gallons of spray in 15 to 20 minutes was designed.

The desirability of applying larvicide at law rates necessitated the development of new equipment to meet these requirements. Future manual larviciding equipment will be much smaller and lighter than the present types, and will greatly increase the productivity of labor engaged in this work.

Improvements in conventional insecticide equipment too nuous to mention have played a part in the development of more effective malaria control techniques.

New drainage and water impoundment techniques

New techniques in drainage and management of impounded waters have appeared. Controlled water fluctuation methods for malaria control are of paramount importance in view of trends toward future developments of this nature. Hess and Kiker (1944) of the Tennessee Valley Authority find the maintenance of high water levels during the spring months successfully suppresses lit-

toral vegetable growth, which in the shallow margins of impoundments gives favorable harborage to mosquito breeding. Superimposed on this is a weekly cyclical fluctuation schedule designed to deter normal littoral anopheline breeding.

No doubt part of the reduction that has been experienced in malaria control is due to better housing conditions. Techniques employed in Public Health education can be credited with assistance in this regard, along with improved economic conditions.

Repellents

A desire to be comfortable, if not a malaria control motivation, may cause more widespread use of insect repellents. Some very effective agents have been developed which will give individual protection far in excess of pre-war formulae. Dimethyl phthalate, indalone, and Rutgers 612 (2-ethyl hexanediol 1-3) are among the best of these, and the Bureau of Entomology & Plant Quarantine find that a mixture of these containing 6 parts dimethyl phthalate and 2 parts of each of the other agents is the most favorable general repellent. These repellents will naturally supplement residual spraying of dwellings as an outdoor safeguard in areas where eradication of the vector is not feasible.

Species Sanitation

During this war the Public Health Service, in cooperation with the several states concerned, engaged in extensive malaria control activities. The program was one of species sanitation. Only three anophelines in the country were considered, because of their demesticated habits and prior incrimination, to be of sufficient importance as malaria vectors to justify their control around the protected zones, and, in most areas, only one of these was to be found. It was possible, therefore, during a period of acute labor and material shortages, to carry out an extensive program with the least drain upon the economy. The savings effected by treating only *A. quadrimaculatus, A. freeborni,* or *A. albimanus* positive breeding places were tremendous. Many ponds in the Southeast which were anopheline positive were merely kept under surveillance and were treated only when they became positive for *A. quadrimaculatus.*

Coordination of Professional Activities

Malaria Control has grown so diverse in its requirements that its attempted execution is no more feasible by a single specialized group than is the operation of a university, or the attempted eludication of the evolution of matter. Then, therefore, we need a close coordination of professional activities, and by this we mean the pooling of diverse specialized knowledge to form coordinated, balanced, and efficient working teams. Progress in this direction had

been made prior to the war, but it has been the pressure of war time requirements that is largely responsible for the present encouraging state of affairs, and, in our opinion, this is one of the most important recent developments in malaria control techniques.

We see in the Army combined engineering-entomological field teams backed by the coordinated efforts of medicine, chemistry, and parasitology. Officers in overall command have flatly stated that such teams have accomplished far more than in the past, when there existed less heterogeneity in training and experience of personnel. This same trend is also noted in the Navy. The Tennessee Valley Authority has been a leader in coordination of professional efforts. Their biologists, engineers, physicians, wildlife and agricultural specialists are pooling their efforts for malaria control and the results obtained are proof of the wisdom of the system.

Probably the outstanding example of this newer coordination for pure malaria control, is to be found in control programs of the State Health Departments in cooperation with the U. S. Public Health Service. The office of Malaria Control in War Areas has 222 commissioned officers who are responsible for malaria control in extra-catonement military areas, and related defense industries. One hundred and one of these officers are engineers, 80 are entomologists or biologists, and 11 are physicians. The remaining 30 are other specialists whose knowledge is indispensable in attaining a well balanced malaria control organization. Among these are statisticians, botanists, chemists, medical technicians and wildlife specialists. Operations of the organization are such that each state or district is assigned balanced professional teams, so that, for instance, drainage planning and execution is done by specialists in that field, after a biological evaluation has shown that mosquito control is justified. Too often in the past, drainage ditches have been dug up hill, so to speak, by workers with no knowledge of engineering practices. Likewise, ditch digging specialists have drained areas of little or no importance in malaria control and of immense value to wildlife conservation. Such blundering mistakes are largely a thing of the past, thanks to the broad minded coordination of professional talents.

In the field of practical investigations and technical development the Henry R. Carter Memorial Laboratory of the M.C.W.A. office is itself an example of extended heterogeneity. There are 26 professional people in this laboratory comprising entomologists, engineers, aquatic biologists, chemists, medical technicians, general biologists, veterinarians, protozoologists and parasitologists. Among the entomologists are specialists in medical entomology, insect toxic-

ology, classification, ecology, physiology and control. The engineers are sanitary, chemical, mechanical and civil. The aquatic biologists are specialists in wildlife conservation. Among the group are some well versed in the working knowledge of immunology, statistics, bacteriology, and pathology. Few problems arise that do not fall within the premise of someone's ability, and we are confident that the work underway could not be accomplished with an equivalent number of people of any single profession.

This trend of professional coordination has extended beyond the individual professions and into organization, and agency cooperation. At no past time have various governmental public and private scientific organizations cooperated more freely than at the present. The Public Health Service, the Army, the Navy, the Bureau of Entomology and Plant Quarantine, the Fish and Wildlife Service, the T.V.A., and numerous university, private and commercial laboratories have worked toward a common goal, and the exchange of day by day data and ideas has, for the most part, been accomplished with little thought of professional or organizational jealousy.

This advance in malaria control techniques is real and of inestimable value. It is something that must be maintained. Reduction in personnel will naturally accompany reconversion, but let us hope that these cutbacks will be proportionately distributed among the various specialties, so that irrespective of the number of people subsequently engaged on malaria control, they will be sufficiently diverse in training and experience to carry forward the multitude of variable and complex problems existing in this field.

To revert to the narrow groove of professional isolationism and intellectual snobbery is a luxury that science, and particularly, malaria control, can, in this day, ill afford.

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DIAGNOSIS, PREVENTION, AND TREATMENT OF TROPICAL DISEASES

Richard P. Strong, Professor of Tropical Medicine, Emeritus, Harvard University. Director of Tropical Medicine, Army Medical School, Colonel, M.C.U.S. Army, etc. Seventh Edition in two volumes ($15.00) or in one volume ($12.00). 398 illustrations (some colored plates) xl + 1747 pages. October 1944 and reprinted February 1945. Philadelphia. The Blakiston Company.

The 7th edition of this well-known work is an enlargement of the 6th edition mainly by adding new material in new pages, viz., 549a, 549b, rewriting portions of some chapters, and by additions in or at the end of chapters by extra paragraphs. In addition to the subject matter indicated by the title, which covers 54 chapters, there is a useful appendix which considers related subjects such as tropical and personal hygiene, indices of clinical and laboratory diagnosis, and disinfectants. Some of the vast volume of work done on tropical disease since the publication of the 6th edition has been included but, as could have been expected simply by limitation of space, this is not comprehensive.

The primary information on malaria is given in the first 135 numbered pages, followed by 27 numbered pages on blackwater fever. In the former, the fact that some old ideas which in the light of present knowledge are not held to be valid, might escape the light reader. The statement, twice made, that the sporozoite enters a red cell does not give the desired connotation of the red cell being entered by a product of, and perhaps quite different from, the sporozoite. The experienced malaria worker might be surprised at the emphasis placed upon diagnosis by fresh preparations as compared to the stained thick-film method which is now so widely used.

The lengths of the fever paroxysms in *P. vivax* and *P. malariae* are listed as being between 4 and 8 hours, whereas recent work has shown the febrile stages average about 10-12 hours in these two species. The listing of *Anopheles darlingi* as an Old World vector is probably due to the misplacing of a section heading as it is apparent from the accompanying description that this mosquito is found in the New World. The unreliable method of giving small quantities of quinine to change quotidian paroxysms in induced *vivax* malaria to tertian periodicity is presented instead of the much more satisfactory use of 0.1 to 0.2 gm. of sodium bismuth thioglycollate.

On the whole, the information is interestingly presented and reads easily. Although repetitions occur, these probably could not have been prevented without a complete rewriting of the subject matter, coordinating the new material with the old.

Even though the research worker might need a more documented treatment of certain particular phases, it could not be expected that such could be obtained in a single volume covering such a large field. For the medical practitioner and other interested in tropical medicine, this book will serve as an excellent reference. It will probably remain a standard for a long time and can be highly recommended. It is attractively bound and well printed. —Martin D. Young.

PLASMA ATABRINE CONCENTRATIONS ATTAINED BY SUBJECTS TAKING 0.1 GRAM OF THE DRUG DAILY

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(Received for Publication 22 October 1945)

Commencing 15 February 1945, all military personnel in the vicinity of Ledo, Assam, India, were placed on a suppressive atabrine regime of 0.1 gram daily (0.7 grams per week). Twenty-one volunteers comprising male and female officers and enlisted men of the personnel of the 20th General Hospital were selected as subjects whose atabrine concentration of the plasma could be followed. None had taken atabrine previously. They agreed to adhere rigidly to the prescribed program, to report for blood drawing on days designated by the Commission, and to abstain from taking atabrine for at least an entire night before reporting for bleeding. We believe that the subjects adhered to their pledges and that violations, if any, were unintentional and inconsequential.

Tests were made at the following weekly intervals after suppressive atabrine was started: 1, 2, 3-4, 5-6, 7-8, 11-12, and 21. Only 14 of the original 21 subjects were able to continue for the entire 21 weeks either because of return to the United States or because of minor ailments attributable to atabrine which necessitated the substitution of quinine.

The tests for plasma atabrine were made by the well-known Brodie-Udenfriend method[3] and the concentrations expressed in micrograms per liter (G/L). Since atabrine was not taken on the days the blood was drawn previous to the bleeding, the values may be considered "minimal."

Results

The individual plasma levels for the 14 subjects under observation for 21 weeks and the mean level for each period of testing appear in Table 1. Table 2 records the levels obtained for the subjects who did not complete the experiment.

Records were obtainable for other subjects, notes on six of whom are here presented by cases:

Female Officer A. One of the original 22 volunteer subjects whom we had to withdraw from the test. At the end of one week plasma level was 21 G/L. On the 11th day an eczematous rash

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[2] T/45, Med. Dept., AUS.

[3] Brodie, B. B., and Udenfriend, S. J., 1943. The estimation of atabrine in biological tissue and fluids, Jour. Biol. Chem. 151:299.

appeared on hands and the level was 45 G/L. Atabrine was discontinued. Two days later (13th day) the level was 34 G/L. The level decreased until the 34th day, when it became zero.

Female Officer B. Recent arrival in theater. Commenced suppressive atabrine 8 May 1945. Requested plasma test on 83rd day on account of deep yellowin gof skin; level, 76 G/L. On 88th day level was 75 G/L. On orders of the Chief of the Medical Service, the dosage was reduced on the latter day to 0.1 gm. every three days. Subsequent levels: 97th day, 52 G/L; 111th day, 38 G/L.

Female Officer C. Requested test on 61st day on account of deep yellowing of skin; level 74 G/L. On orders of the Chief of the Medical Service, atabrine was discontinued until the 71st day, when the level was 44 G/L. Atabrine was resumed, 0.1 gm. every 2 days. On the 105th day the level was 48 G/L.

Female Officer D. Requested test on 147th day because of deep yellowing of the skin; level, 48 G/L. When questioned after the test she admitted having taken an atabrine tablet "about an hour" before the blood was drawn. She reported next day without having previously taken atabrine and the level was 38 G/L.

Male Officer A. Requested test on the 64th day because of deep yellowing of the skin; level, 56 G/L.

Male Officer B. Admitted to hospital 127th day for skin condition; level, 48 G/L.

Discussion

Tables 1 and 2 show the blood levels attained in a group of normal volunteer subjects who, if they kept their pledges, conformed strictly to the atabrine regime prescribed for them. The

Table 1.—Atabrine levels (G/L) attained by 14 subjects over a period of 21 weeks

Number	Weeks after starting suppressive atabrine						
	1	2	3-4	5-6	7-8	11-12	21
1	14	20	23	30	35	34	24
2	14	30	21	21	20	16	18
3	13	18	20	22	24	28	25
4	17	30	25	24	26	25	22
5	13	30	28	19	22	24	22
6	12	20	16	15	24	29	18
7	17	38	17	34	32	34	28
8	12	24	20	24	26	32	28
9	21	16	27	21	24	34	24
10	10	14	18	21	22	22	20
11	12	26	15	16	18	16	20
12	12	24	24	20	18	22	24
13	4	12	18	19	20	24	26
14	22	26	26	25	24	28	20
Mean	13.8	23.4	21.3	22.4	24.0	26.0	22.8

results agree with those obtained by other workers insofar as they show that individuals differ considerably in their ability either to absorb atabrine or to retain it in the plasma. The levels for Nos. 1, 7, 8, and 9 on the fifth week or thereafter were in general consistently higher than the average, while Nos. 11, 15, 18, and 21 were below the average. No. 18, for example, was consistently low, so low in fact that it is doubtful if he was protected. Naturally we suspected his good faith, but as an enlisted man of the detachment he took his atabrine daily under the eyes of the Administrative Officer of the Day and his general attitude was sincere and cooperative. He attributed his low level to the profuse sweating he experienced during his almost daily exertions at baseball in the tropical climate.

The results are unique in that the mean levels attained at the end of the second week are very close to the mean levels attained on any subsequent week. Previous workers have reported a steady rise up to sometime between the fourth and sixth week before a maximum level was attained. We have no explanation to offer except the following: (1) Previous records available to us were for subjects who took 0.6 gm. of atabrine per week. Ours took 0.7 gm. (2) The weather was very cool during the first two weeks which commenced 15 February 1945. Contradicting this is previous work showing that perspiring and physical exertion under tropical conditions may not influence the plasma level seriously. (3) Geographical situation, diet, and certain other conditions were different. There were, however, notable exceptions to this finding regarding mean levels. In certain individual cases (Nos. 1, 3, 9, etc.) the levels at the end of the second week were lower than subsequently.

Subjects Nos. 13 and 16 were especially notable exceptions. The levels of No. 13 rose steadily from 4 G/L at the end of the first week to 26 G/L at the end of 21 weeks. This subject, the Chief of the Medical Service, took his atabrine regularly throughout. He

Table 2.—Atabrine levels (G/L) attained by 7 subjects under observation less than 21 weeks

Number	Weeks after starting suppressive atabrine					
	1	2	3-4	5-6	7-8	11-12
15	9	14	13	13	14	—
16	6	10	20	27	32	—
17	14	17	24	—	—	—
18	9	13	10	10	8	16
19	14	14	20	21	18	—
20	12	24	20	24	20	18
21	14	16	12	14	20	—
Mean	11.1	15.4	17.0	18.2	18.7	17.0

commented upon the fact that he had diarrhoea in the early days of the experiment, a fact which may have been responsible for his failure to attain a higher level. No. 16, however, was a similar case except that he experienced no diarrhoea. Hence it is not possible to draw the conclusion that diarrhoea was a factor in preventing absorption.

There was in the entire series no case in which the plasma level attained a value higher than 38 G/L. There came to our attention, however, the six above-recorded cases with unusually high levels attained on one tablet of atabrine a day. Female Officer A was originally one of the subjects in a group under study. At the end of 7 days her level was 21 G/L. At the end of 11 days she noted a skin condition on her hands which she called to the attention of the Medical Service. A plasma atabrine test was ordered, the result of which was 45 G/L. Thus in 11 days this female officer's plasma concentration rose to the unusual level of 45 G/L. Twenty-three days after atabrine was discontinued her blood was again free of atabrine.

Female Officer B attained a level of 76 G/L on the 83rd day. Female Officer C had a level of 74 G/L on the 61st day. Female Officer D had a level somewhere between 38 and 48 G/L on the 147th day. Male Officers A and B attained levels of 56 G/L and 48 G/L on the 64th and 127th days, respectively. In all but the last of these cases there was extreme yellowing of the skin. Even Female Officer A's skin was yellower than that of the others in the test who, incidently, showed little coloration during the first two weeks. We believe that extreme yellowing of the skin is usually but not necessarily indicative of a high blood level in dark complexioned people. On the other hand, one of us noted a dark complexioned officer whose skin was almost a pumpkin yellow. He was invited to have a test made and a plasma level of 20 G/L was found.

Summary

The mean plasma atabrine levels of a group of 14 individuals under observation for 21 weeks commencing 15 February 45 in Assam, India, stabilized within two weeks on a suppressive atabrine regime of 0.1 gm. daily at values ranging from 21.3 G/L to 26.0 G/L. A group of seven others who started at the same time attained somewhat lower means, apparently because this group contained four individuals who might be called "poor absorbers." There was considerable varaition in the ability of individuals to attain blood levels recognized as satisfactory for suppression. These groups contrined no individuals who exhibited extraordinarily high blood levels, but a number of such cases were encountered in the course of other studies and are herewith described.